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Non-Point Source Studies on Chesapeake Bay III. Relationship between Bacterial Contamination and Land Use in the Rhode River Watershed, and Survival Studies of 'Streptococcus faecalis' in the Estuary

Smithsonian Institution, Edgewater, Md.

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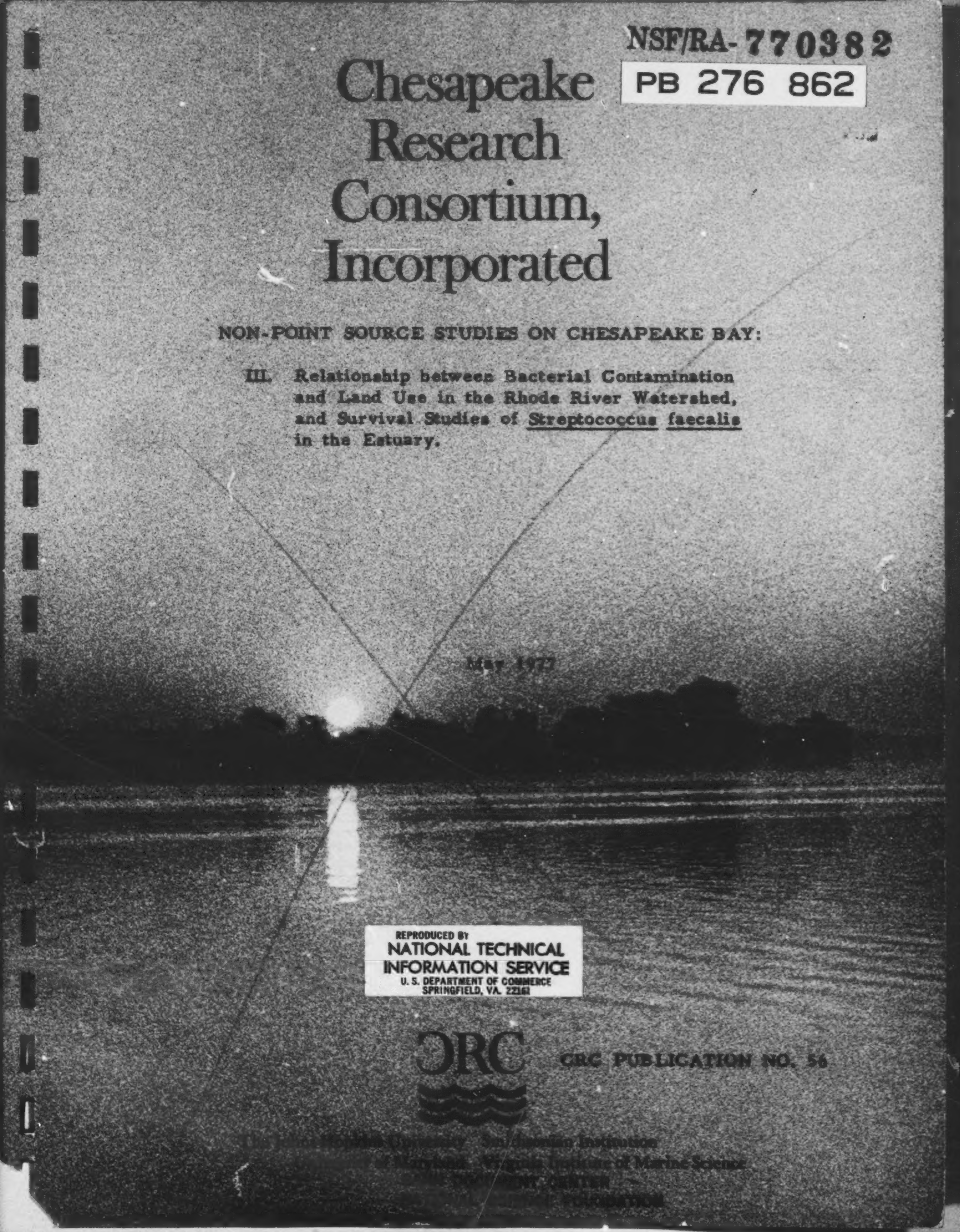

Chesapeake Research Consortium, Incorporated

NON-POINT SOURCE STUDIES ON CHESAPEAKE BAY:

III. Relationship between Bacterial Contamination and Land Use in the Rhode River Watershed, and Survival Studies of *Streptococcus faecalis* in the Estuary.

May 1977

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In Part III of this project, the contribution of 983 hectare of rural watershed to the fecal coliform (FC) and fecal streptococci (FS) pollution in water runoff entering the Rhode River was examined. The survival of Streptococcus faecalis MC-5 of fecal origin in the Rhode River estuary as affected by time, water temperature, dissolved oxygen, salinity and montmorillonite in diffusion chambers was determined. As a result of this study the following conclusions were made: (1) The effect of basin characteristics was the same on FC and FS discharge and on water flow; (2) Fecal coliform pollution in runoff water varies with the seasons of the year; (3) The contribution of each land use component to FC and FS discharge in a multiple land use watershed can be calculated by the use of a statistical model; (4) Water temperature is the most important factor in predicting fecal streptococci survival from point and non-point sources in assessing water quality in an estuarine system.

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III. Relationship between Bacterial Contamination and Land Use in the Rhode River Watershed, and Survival Studies of *Streptococcus faecalis* in the Estuary.

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Any opinions, findings, conclusions
or recommendations expressed in this
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and do not necessarily reflect the views
of the National Science Foundation.

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ABSTRACT

The contribution of 983 hectare of rural watershed to the fecal coliform (FC) and fecal streptococci (FS) pollution in water runoff entering the Rhode River was examined. The survival of Streptococcus faecalis MC-5 of fecal origin in the Rhode River estuary as affected by time, water temperature, dissolved oxygen, salinity and montmorillonite in diffusion chambers was determined.

As a result of this study the following conclusions were made: 1. The effect of basin characteristics was the same on FC and FS discharge and on water flow; 2. Fecal coliform pollution in runoff water varies with the seasons of the year; 3. The contribution of each land use component to FC and FS discharge in a multiple land use watershed can be calculated by the use of a statistical model; 4. Water temperature is the most important factor in predicting fecal streptococci survival from point and non-point sources in assessing water quality in an estuarine system.

The following publication resulted from this investigation: Faust, M. A. and N. M. Goff, 1977. Basin size, water flow and land-use effects of fecal coliform pollution from a rural watershed. In Watershed Research in Eastern North America. Chesapeake Bay Center for Environmental Studies, Smithsonian Institution, Edgewater, Md. Feb. 28 - March 3, 1977. Smithsonian Institution publication.

SUMMARY

A comprehensive study was undertaken on the effects of a series of environmental variables on fecal coliform (FC) and fecal streptococci (FS) discharge from 983 ha of Rhode River watershed. Seven subwatershed basins, ranging in size from 28 to 254 ha, were instrumented to monitor water discharge rates. Of the monitored watershed area, 61% was forest and old field, 16% was cultivated cropland, 18% was pasture, while the remaining 5% was residential and fresh-water wet areas. The average human and livestock densities of these basins are 0.31 person ha^{-1} and 0.53 livestock ha^{-1}. Water discharge estimated by weekly spot sampling of water flow was significantly correlated with weekly automated flow measurements ($R^2 = 0.992$). Therefore, weekly spot sampling data was used to establish FC discharge from the basins. Water runoff was positively correlated with basin size ($R^2 = 0.973$) and stream length ($R^2 = 0.922$). Fecal coliform discharge was also positively correlated with water flow at all weirs at all seasons, with stream length ($R^2 = 0.799$) and with basin size ($R^2 = 0.900$). Fecal coliform discharge from three land uses was also estimated. From pasture the discharge was 89×10^9 FC $ha\text{-}year^{-1}$, from forest 22.4×10^9 FC $ha\text{-}year^{-1}$ and from cultivated land 19.8×10^9 FC $ha\text{-}year^{-1}$. From the entire study area 68% of FC was discharged from pasture, 17% from forest and 15% from cultivated land.

Fecal streptococci discharge was governed by the same environmental variables and basin characteristics as FC. Discharge of FS was positively correlated with water flow at all weirs at all seasons, with stream length ($R^2 = 0.717$) and with basin size ($R^2 = 0.772$). Larger basins discharged

more bacteria per year than smaller basins and also had larger proportion of pasture of the total basin area. Fecal streptococci discharge from three land uses were: from pasture 15.11 x 10^{10} FS ha-year^{-1}, from forest 0.95 x 10^{10} FS ha-year^{-1} and from cultivated land 1.67 x 10^{10} FS ha-year^{-1}. Thus, 85% of total FS discharge was derived from pasture, 9.4% from cultivated and 4.4% from forested areas.

Survival of *S. faecalis* MC-5 of fecal origin in an estuarine environment as affected by selected physical parameters in diffusion chambers has been elucidated. Water temperature, time, dissolved oxygen, salinity and montmorillonite were recorded simultaneously and viable cell numbers were estimated. The survival of bacteria varied seasonally. Montmorillonite addition did not extend survival of *S. faecalis* MC-5. The slope between viable cell numbers and water temperature increased about 100% for each 10 C increment in temperature and gave a correlation coefficient of $r = 0.892$. A similar correlation coefficient $r = 0.569$, was obtained between water temperature and t 1/2 of the initial cell population. In all experiments regressions were performed considering all variables after bacteria had been in the Rhode River environment for 3 days. Coefficient of multiple determination was estimated as $R^2 = 0.753$. Approximately 75.3% of the variance of viable cell numbers can be explained by variation in water temperature, dissolved oxygen, and salinity.

PROJECT OBJECTIVE

1. To estimate concentrations and total discharge of fecal coliform, fecal streptococci,salmonella and total viable aerobic heterotrophic bacteria on a seasonal basis, per unit watershed area of a series of land use types characteristic of the Chesapeake Bay region.
2. To determine the relationship between water discharge and bacteria discharge affected by basin characteristics such as basin size, stream length, drainage density and land use practices at 7 Rhode River basins from non-point sources.
3. To examine these factors and the probability of calculating fecal bacterial discharge from single land use areas, namely pasture, cultivated and forest land which may contribute significantly to the bacterial pollution of the estuary.
4. To assess the effect of physical parameters, such as time, temperature, dissolved oxygen, salinity and clay concentrations on the *in situ* survival of *Streptococcus faecalis* within the tidal waters of the Rhode River estuary.

INTRODUCTION

The presence of pathogenic bacteria in water runoff from a rural and urban area is a major concern among the many sources of water pollution. This type of pollution can not be corrected by usual sanitary treatment practices (19, 29, 35, 36). During the past two years extensive data have related the presence of fecal coliform (FC) bacteria to runoff water from the Rhode River watershed (14, 15). Thus far no comparison had been made between FC and fecal Streptococci (FS) contribution from the watershed. Estimation of FC and other indicator bacteria from the watershed would allow a more complete assessment of fecal pollution of the entire Rhode River watershed-estuary. Furthermore, a comparison on the fecal pollution contributed by a rural watershed would give us valuable information about the presence of man, land use practices and water quality.

Changes in land use or man made disturbances in the watershed almost certainly effect the rate of indicator bacterial discharge from the land. Information is limited however, on two key factors: (1) the dependence of microbial densities on basin characteristics and the hydrological regime of the watershed and (2) the contribution of various land use practices to the level of indicator bacteria in the runoff.

Fecal coliform bacteria levels in the estuaries of Chesapeake Bay is very important, because presently it is the major indicator organism of water quality for shellfish production (2). If FC numbers exceed 14 FC MPN/100 ml of water for a period of time, the area is considered unsafe for shellfish harvesting.

The contribution of watershed runoff to pollution depends on the characteristics of the watershed and the physical-chemical characteristics of the aquatic environment which determine the persistence of fecal bacteria. Coliform levels in water runoff have been reported to depend on the rates of water discharge (13, 27), hydrologic regime of the stream (36), natural background coliform concentrations and soil types (3, 18, 27) seasonal differences (11, 14, 15, 21, 29) nutrient availability (23) and sediment load (24). The survival of coliform bacteria in the estuary depends on the physical-chemical conditions of the aquatic environment (16, 18) which change seasonally. Their concentrations also depend upon their rate of dilution in a tidal estuary (14, 25).

Most studies have been concerned with watersheds of fresh-water rivers. Some investigators studied relatively small watersheds 1-25 ha in size (21, 27, 36), others studied large watersheds of rivers (29). A few studies which touched upon saline estuarine waters determined the density of coliform bacteria in the water only, without surveying the contribution of the watershed in detail (7, 17, 31, 34).

We have measured the contribution of 849 ha of rural watershed to the FC pollution of the Rhode River (11, 14, 15). This rural watershed contributed substantial quantities of FC to the estuary (11, 14). We have correlated FC numbers with volume of water runoff, watershed area (ha) and domesticated animal density of each sub-watersheds of the Rhode River under study. Bacterial flora in the runoff water changed seasonally reaching the highest values in May, June and December. Fecal coliforms reached levels in the runoff 1.1 x 10^9 bacterial/ha-day or 5.3 x 10^9 bacteria/day-animal. From the FC discharge and survival data, we estimated that 2600 m^3 of well mixed receiving water was needed for every ha of watershed area not to exceed the safe water standard. Today, knowing the FC discharge data at the weir sites, we can calculate and predict the water quality standard for shellfish harvesting along the RR estuary in the portion of the river to which the rural watershed contributes FC bacteria.

An essential part of the fecal pollution in the water is the knowledge of the survival of fecal bacteria in the estuary (16, 37). The survival rate of FC is longer at low water temperatures (0-10 C) and the bacteria die off quickly when water temperature exceeds 20 C. Bacterial dilution and mixing by the tidal movement and wind speed/addition in to water temperatures greatly affect bacterial survival.

Fecal streptococci are also widely distributed in the environment (18, 19). Fecal streptococci have been recovered from rivers and streams in remote areas devoid of any apparent human fecal contamination as well as from urban streams subjected to fecal pollution from humans and other animals. Unfortunately much less data is available about their presence in the runoff water from rural watersheds.

This report presents information concerning two areas: 1. the extent of stream pollution regarding overland transport of indicator bacteria as a function of basin-wide land use; 2. survival of *S. faecalis* in the estuarine environment. More specifically: 1. We have estimated FC and FS discharge in water runoff by surveying the relationship between water discharge and bacterial discharge affected by basin characteristics such as basin size, stream length, drainage density, and land use practices at 7 Rhode River basins. We examined these factors and the probability of calculating total FC and FS discharge from single land use area, namely pasture, cultivated and forest land which may contribute significantly to the FC pollution of receiving estuarine waters of the Chesapeake Bay. 2. Survival of *S. faecalis* was investigated in diffusion chambers exposed to a natural estuarine environment. The effect of physical parameters such as time, temperature, dissolved oxygen, salinity and clay concentrations on the *in situ* survival of *S. faecalis* were elucidated. The possibility of cell injury was also determined by comparison of detection and enumeration of *S. faecalis* populations on nutritionally rich non-selective versus selective media.

MATERIALS AND METHODS

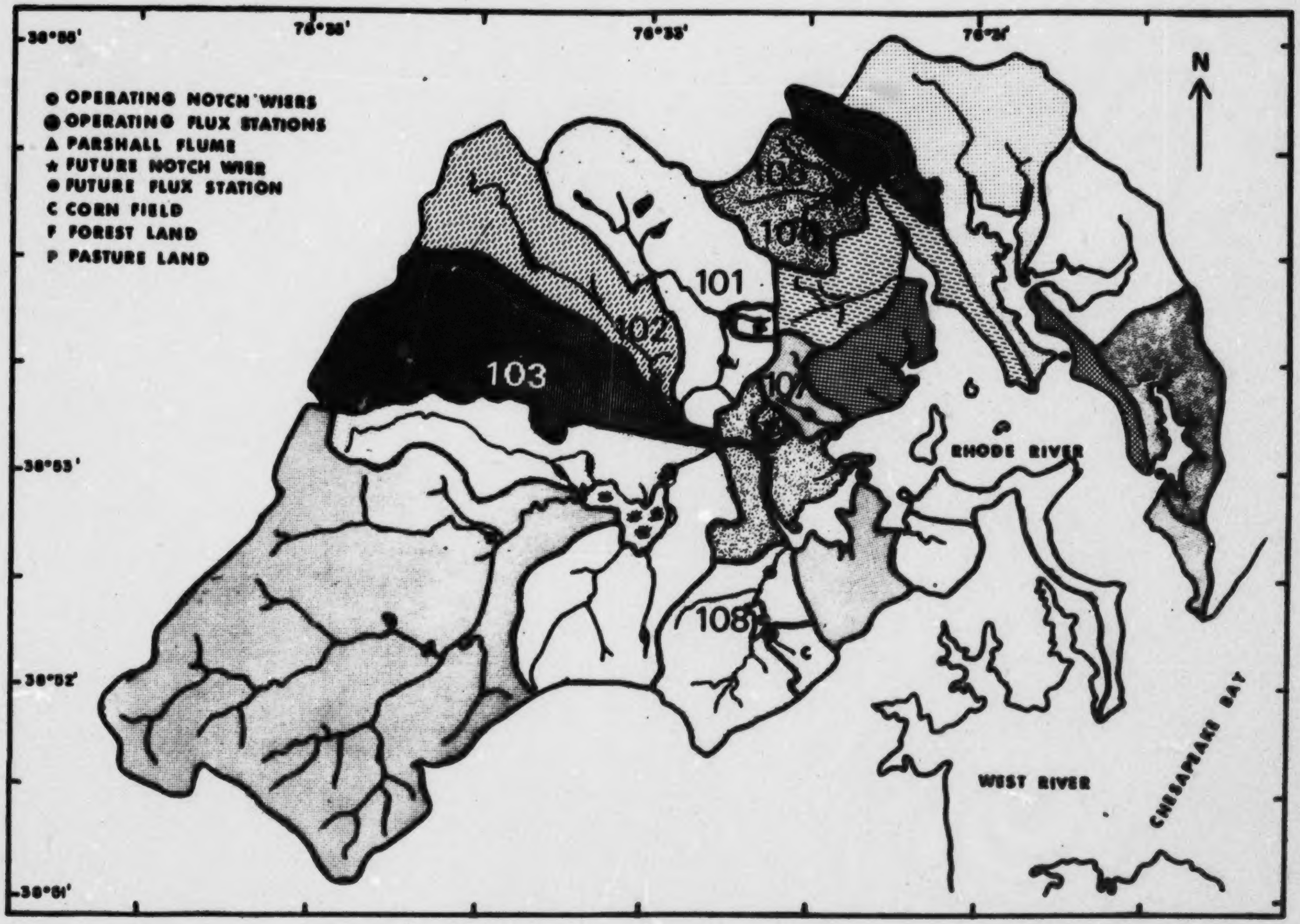
Description of the Watershed

The Rhode River watershed is located on the western shore of the Chesapeake Bay, south of Annapolis, Maryland and has a total watershed area of 3332 ha. The research presented here includes only 7 subwatershed basins as study areas shown in Fig. 1. The 7 basins have a total area of 983 ha (Table 1).

The designation and size of the seven basins are as follows: North Branch (101), 226 ha, Blue Jay Branch (102), 192 ha, Williamson Branch (103), 254 ha, and Steinlein Branch (108), 150 ha, all of which drain into Muddy Creek. Sellman North (105), 37 ha, and Sellman South (106), 95 ha, drain into Sellman Creek. Fox Creek (107), 28 ha, drains directly into Rhode River.

Land use of these basins is divided into the following categories: row crops, upland wet areas, tidal marshes, forest and old fields, pasture and non-sewered residential areas (Table 1). Of the 7 basins 61% include forest and old field, 16% cultivated cropland and 18% pasture, while the remaining 5% is residential and freshwater wet areas. Sanitary effluents are never deliberately a component of the stream flow, all of it being disposed of in septic tanks.

Fig. 1. Map illustrates the 24 subwatershed basins of the Rhode River. The full name of the seven monitored subwatershed basins and their abbreviations are as follows: North Branch Sellman Creek (105), South Branch Sellman Creek (106), Fox Creek (107), North Branch Muddy Creek (101), Blue Jay Branch Muddy Creek (102), Williamson Branch Muddy Creek (103), and Steinlein Branch Muddy Creek (108). The locations of the weirs are marked by open circles.



76°35'
76°33'
76°31'
38°55'
38°53'
38°52'
38°51'
N
○ OPERATING NOTCH WIERS
● OPERATING FLUX STATIONS
▲ PARSHALL FLUME
★ FUTURE NOTCH WIER
● FUTURE FLUX STATION
C CORN FIELD
F FOREST LAND
P PASTURE LAND
101
102
103
108
C
RHODE RIVER
WEST RIVER
CHESAPEAKE BAY

Table 1. Land use categories of seven Rhode River basins.

Basin	Pasture	Forest	Cultivated	Hayfield	Oldfield	Wetland	Residential	Total ha
			% of Total Area					
101	26.9	37.9	9.5	0.3	18.4	0.1	6.0	225.8
102	18.3	47.3	18.2	3.4	6.7	0.5	5.6	191.7
103	12.5	62.7	2.0	4.1	14.0	0.2	4.5	253.5
105	2.1	31.2	13.3	4.0	49.0	0.0	0.4	37.5
106	20.6	44.9	12.8	15.4	5.0	0.0	1.3	95.3
107	9.0	59.6	8.6	0.0	16.6	0.7	5.5	28.2
108	10.8	38.7	23.4	9.5	13.5	0.9	3.2	150.2

The human and livestock populations of each basin varies. The average human and livestock densities of these watersheds are very low, comprised of 0.31 persons ha^{-1} and 0.53 livestock ha^{-1} basin area (14).

The geography of the Rhode River watershed is described in detail elsewhere (10). Low elevation aerial photos and topographic maps were used to determine basin size, stream length and land use. Drainage density was estimated by dividing stream length of all stream segments by the drainage basin area (26). Land use practices are updated by personal interviews of the farmers on the watershed. The rainfall averages 120-130 cm per year. The streams draining the watershed have low water discharge, except during extensive rainfall and are often dry during extended dry weather.

Water Flow Estimation

Water flow designated as integrated flow is estimated at sampling sites equipped with weirs of V-notch type design and are instrumented to monitor water discharge rates and to automatically take volume average water samples (11). Water flow of spot samples was estimated from the instantaneous flow rates when the samples were collected and expressed as flow/day, week, month and year at each weir location (Table 2).

Bacterial Analyses

A. Indicator Bacteria in Water Runoff

Pathogenic bacteria that are indicators of fecal pollution and water quality were estimated. These bacteria are total coliforms, fecal coliforms, fecal Streptococci and Salmonella. Water samples were collected in sterile screw-capped bottles by immersion in the stream with the opening held upstream just below the V-notch and returned to the laboratory within 3 hours of collection. Water discharge rates were estimated at the time of the day when

Table 2. Daily mean water discharge from seven Rhode River basins.

Month	Basins 101	 102	 103	 105	 106	 107	 108
	$L \times 10^6$/day						
December	7.19	10.52	8.14	- *	-*	0.29	15.31
January	1.94	1.64	1.79	0.75	1.54	0.36	1.80
February	1.87	1.71	1.79	0.30	0.68	0.18	1.11
March	3.72	3.17	3.73	0.77	1.44	0.40	2.05
April	1.89	1.44	2.17	0.27	0.60	0.19	1.14
May	2.40	2.06	2.70	0.41	2.20	0.18	1.61
June	0.65	0.36	1.62	0.06	0.39	0.07	0.48
July	8.32	4.32	5.24	1.60	3.20	0.63	3.50
August	0.78	0.46	0.77	0.06	0.15	0.06	0.28
September	1.82	1.38	1.47	0.27	0.56	0.06	1.09
October	2.28	1.74	2.03	0.33	0.80	- **	1.49
November	1.74	1.42	2.06	0.25	0.65	- **	1.34

* Basin not yet instrumented to estimate water discharge.

** Weir inoperable

samples were taken at each weir location. Samples were collected at weekly intervals. Fecal coliform FS and Salmonella concentrations were estimated as recommended and described in Standard Methods for Examination of Water and Waste Water (1). Two methods were used, the Membrane Filter and Multiple Tube Fermentation techniques. The Multiple Tube Fermentation technique was used to estimate FC, FS and Salmonella from December 1974 through June 1975 and bacterial concentrations were expressed as MPN/100 ml. The Membrane Filter technique was employed from July through November 1975 and FC and FS numbers were expressed as cells/ml. To estimate bacteria discharge from a given basin, concentration of bacteria and water discharge rates were multiplied.

1. Total and Fecal Coliform Bacteria

a. Membrane Filter (MF) technique was used as follows: The size of the water sample was governed by the expected bacterial density. The filters were transferred to M-Endo Broth and incubated 22-24 hr at 35 C. Typical coliform colony with pink to dark red color with a metallic sheen, were counted and total coliforms present in the samples were estimated (1).

Determination of fecal coliforms by MF technique was as follows: Appropriate amount of water sample was filtered through a sterile membrane filter. The Filters were placed on M-FC broth and incubated for 24 hr at 44.5 C. Blue colonies characteristic of fecal coliforms were counted.

b. The Multiple Tube Fermentation technique was used to estimate total coliform bacteria by inoculating into each 3 tubes of Lactose Broth 10, 1, and 0.1 ml of water samples. These test tubes were incubated for 24-48 hr at 35.5 C. Positive tubes that produced acid and gas were estimated as total coliform bacteria in the sample.

Fig. 2. Identification of Total (TC) and Fecal Coliforms (FC) in selected water samples estimated between September and November 1975.

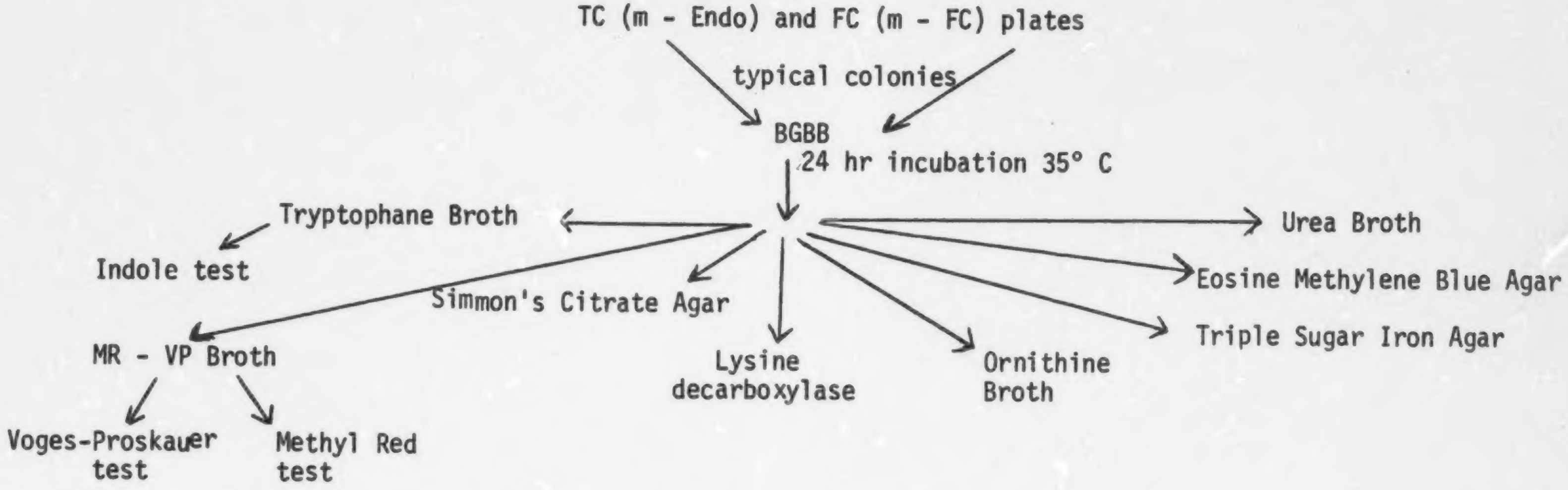

TC (m - Endo) and FC (m - FC) plates
typical colonies
BGBB
24 hr incubation 35° C
Tryptophane Broth
Indole test
Simmon's Citrate Agar
MR - VP Broth
Voges-Proskauer test
Methyl Red test
Lysine decarboxylase
Ornithine Broth
Urea Broth
Eosine Methylene Blue Agar
Triple Sugar Iron Agar

Table 3. Scheme of total and fecal coliforms identification according to Blair et al (5).

Tests on substrates	E. coli	Enterobacter		Citrobacter	Klebsiella
		aerogenes	cloaceae		
Indole	+	-		D (+)	-
Methyl red	+	-		+	d
Voges-Proskauer	-	+		-	D (+)
Citrate (Simmon's)	-	+	+	+	d (+)
Triple sugar Iron agar (H_2S)	-	-		D (+)	-
Lactose	+ or x	+		+ or x	D
Lysine decarboxylase	+	(D) +	-	-	d (+)
Ornithine	d	+	+	d	-
Urea hydrolysed	-	d (-) or	(+)	(+)	d (-) (+)
Eosine Methylene Blue agar	+ (metallic sheen)				

D = different reactions given by different species of a genus

d = different reactions given by different strains of a species or serotype

x = late or irregular positive

Positive cultures were further tested for the presence of fecal coliforms. An aliquot of the positive cultures was transferred to test tubes containing EC Broth, incubated in a water bath for 24 hr at 44.5 C. Positive cultures producing acid and gas at the elevated temperature within 24 hr indicated the presence of fecal contamination.

c. Identification and confirmation of selected typical colonies taken from the surface of M-Endo and M-FC plates were used to confirm TC and FC bacteria in selected water samples between September and November, 1975 (Fig 2). The Indole- Methyl Red-Voges-Proskauer-citrate (IMViC), Triple Sugar Iron Agar (TSI), Eosine Methylene Blue (EMB) utilization by bacteria were tested as described in Standard Methods (1). Lysine and ornithine decarboxylase and urea hydrolyzing enzymes presence were used as described by Blair et al.(5) according to the scheme listed in Table 3.

2. Total and Fecal Streptococci

a. Multiple Tube Fermentation technique: sodium azide dextrose broth was used to determine MPN of total Streptococci. Turbidity was used to indicate positive result. Samples from positive tubes were transferred to ethyl violet azide broth. Test tubes showing turbidity and sedimentation with purple coloration were interpreted as positive indicating Fecal Streptococci (1).

b. Membrane Filtration technique: KF - Streptococcus broth was used to enumerate Streptococci. Colonies that appeared red to pink on the filters indicated FS contamination (20).

c. Identification - confirmation: Identification of FS bacteria was accomplished by selecting at random typical FS colonies from the membrane filters. The colonies were inoculated into KF - streptococcus broth at 35 C

Table. 4. Identification of Fecal Streptococci in selected water samples estimated between October 1975 through August 1976.

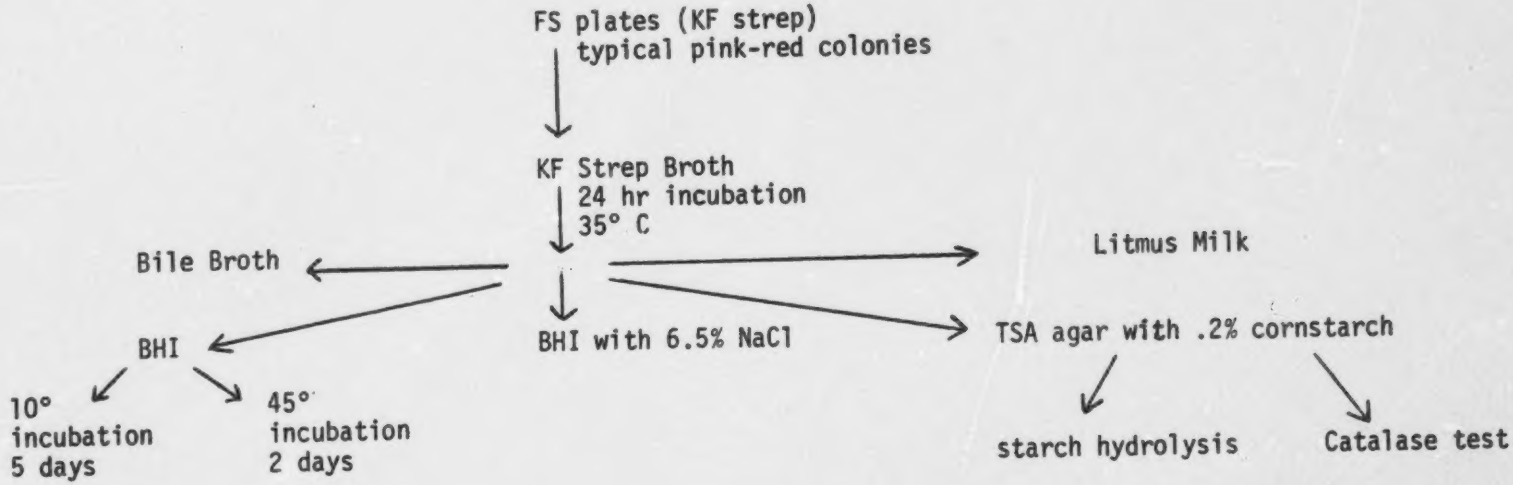
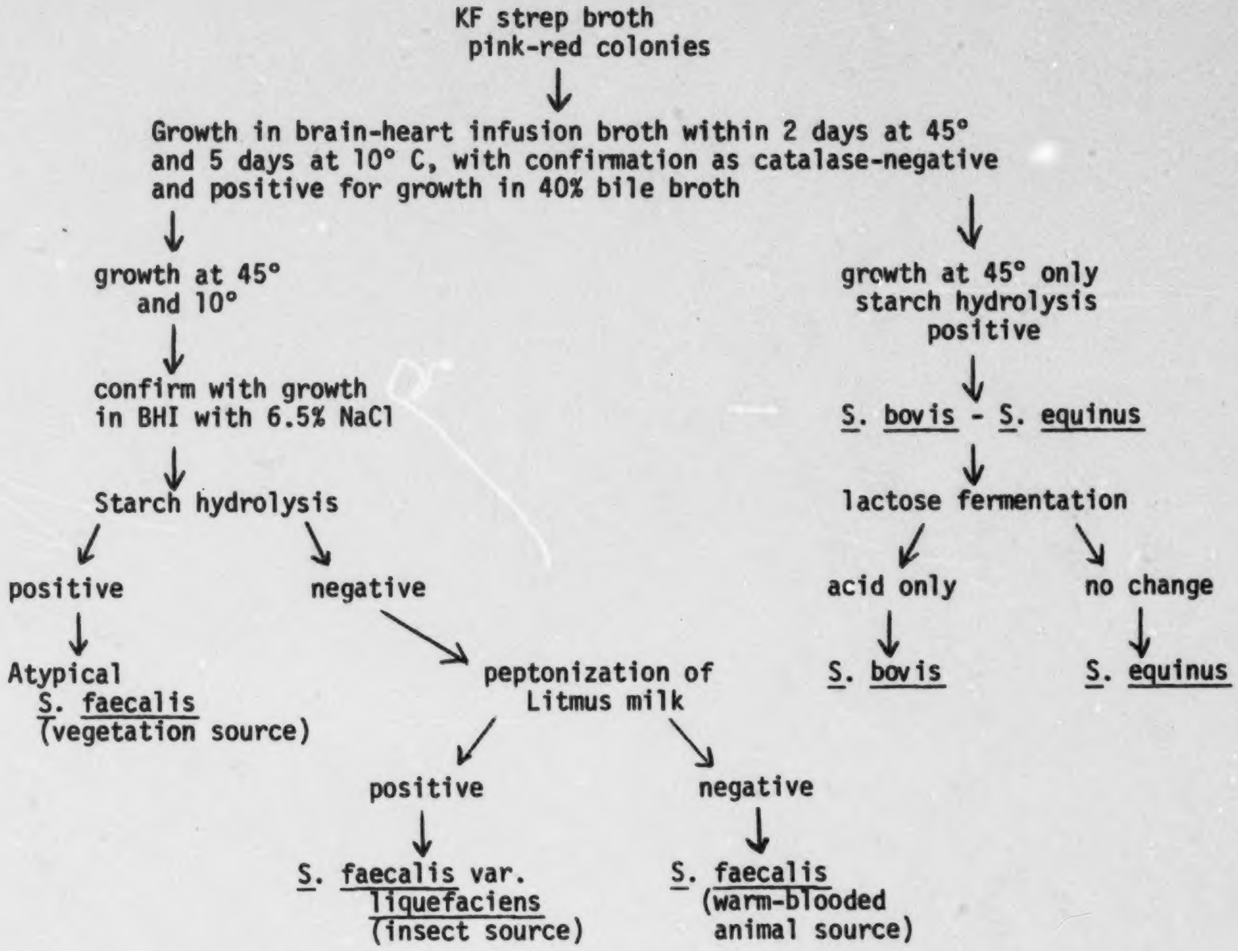

FS plates (KF strep)
typical pink-red colonies
KF Strep Broth
24 hr incubation
35° C
Bile Broth
BHI
10°
incubation
5 days
45°
incubation
2 days
BHI with 6.5% NaCl
Litmus Milk
TSA agar with .2% cornstarch
starch hydrolysis
Catalase test

Table 4 continued


KF strep broth
pink-red colonies
Growth in brain-heart infusion broth within 2 days at 45° and 5 days at 10° C, with confirmation as catalase-negative and positive for growth in 40% bile broth
growth at 45° and 10°
confirm with growth in BHI with 6.5% NaCl
Starch hydrolysis
positive
Atypical S. faecalis (vegetation source)
negative
peptonization of Litmus milk
positive
S. faecalis var. liquefaciens (insect source)
negative
S. faecalis (warm-blooded animal source)
growth at 45° only starch hydrolysis positive
S. bovis - S. equinus
lactose fermentation
acid only
S. bovis
no change
S. equinus

for 24 hr. Cell suspensions were transferred to Brain-Heart Infusion Broth (BHI) for inculation at 10° and 45° C, to BHI with 6.5% Na Cl, Bile Broth, Litmus milk and Trypticase Soy Agar with 0.2% starch added. Typical colonies were identified by the scheme of Geldreich and Kenner (20) also listed in Fig. 4.

3. Salmonella

The Multiple-Tube Fermentation Technique dilution series of Selenite-Cystine Broth was used to determine the MPN of Salmonella-like organisms (1). Test tubes were incubated for 48 hrs. at 35° C. Turbidity was used to indicate a positive test. Samples from positive tests were streaked on Hektoen Enteric Agar and plates incubated for 24 hrs. at 35° C. Several positive cultures were further tested on Triple Sugar Iron Agar and slants incubated for 24 hrs. at 35° C. Suspected Salmonella organisms were tested further for phenylalanine deaminase activity. Negative phenylalanine deaminase tests indicated the presence of Salmonella in the water (5). Bacterial numbers were determined as MPN/100 ml of water.

4. Bacteria other than Pathogenic Bacteria

Water samples were diluted in sterile 0.01 M phosphate buffer pH 7.5 and plated on Nutrient agar collected from the weir stations. Each sample was plated in triplicate on the above media at each of two dilutions. Dilutions ranged from 10^1 - 10^4, depending upon the numbers of the population expected to be present. Plates were incubated at room temperature (18-20° C) for seven days (1).

B. Land Use - Fecal Coliform and Streptococcus Relationships

1. Statistical Model: The seven basins under consideration have complex land use patterns which makes it difficult to determine indicator bacteria discharge from a specific land use. A statistical model which relates

bacterial discharge to land use was used to determine the proportion of FC and FS discharge originating from each of three land use categories: cultivated land (including residential areas and hay fields), pasture land and forested areas (including old fields and fresh water areas) (8). The model includes the area of land use in ha and the estimated FC or FS discharge values from each basin. By applying a linear model which relates land use to bacteria discharge, the proportion of FC or FS for each land use was estimated. No statistical weighing factors were used in the model for this application. Fecal coliform and streptococci discharge land-use relationship were estimated from yearly FC and FS discharge data from seven basins.

2. Data analysis: The relationship between water discharge, FC discharge, and basin characteristics was explored as it was of interest to obtain general equations for these parameters. For each treatment the dependent variable (y) was water discharge or FC discharge and independent variables (x) were basin size, stream length, drainage density. The data was analyzed by two methods: 1) A least squares regression analysis in the form $Y = a + b X$, giving the best fit of the data where a is the intercept and b is the slope; 2) Fecal coliform discharge and water discharge however, appeared to be related exponentially. The best fit of the data could be related by a parabolic regression equation of the form of $y = a_\circ + a_1 x + a_2 x^2$; y = FC discharged year^{-1}, x = water flow year^{-1}, and $a_\circ$, a_1 and a_2 are constants. The program also calculated R^2 (the coefficient of determination, which gives the proportion of y explained by the equation), the F value and t-test (for testing the statistical significance of the equations). One asteric* indicates statistically significant relationship at 95% probability levels and two asterics** indicates statistically significant values at 99% probability level. All data compilation was done using Hewlett-

Packard HP-9810 and PH-9830 calculators with extended memory, tape drive and typewriter.

C. Survival of Fecal Streptococci

1. Isolation: The bacterium used in this study was isolated from Muddy Creek within the Rhode River estuary. It was identified as S. faecalis by growth in KF-broth and on Brain-Heart Infusion Broth within 5 days at 10 C and within 2 days 45 C temperature, negative starch hydrolyzis, litmus milk peptonization and catalase negative reactions (20). This bacterium was designed as S. faecalis MC-5. All cultures used in the experiments were grown in trypticase soy broth (TSB) for 24 hr. at 37 C. Cells were harvested by centrifugation at 2900 rpm for 20 min. and were either washed twice with sterile standard phosphate buffer (16) or with gelatin phosphate buffer (4). The gelatin phosphate buffer consisted of 0.2% gelatin, 0.73% KH_2PO_4 and 0.37% K_2HPO_4, and the standard phosphate buffer consisted of 0.14% KH_2PO_4 and 0.17% K_2HPO_4 at pH 7.0. After the final wash, cells were resuspended and diluted in designated buffers to the desired population density using a Beckman DU Spectrophotometer set at 600 nm wave-length. Bacteria were diluted, plated, and counted according to Standard Methods (1).

2. Survival Experiments: Diffusion chambers were purchased from their designers McFeters and Stuart (23). Nucleopore filters of 0.45 µm pore size and 9.0 cm diameter (Nucleopore Corp.,Pleasanton Calif.) were used.Chambers and filters were sterilized using ultraviolet light before each chamber was filled with 20 ml cell suspensions as described previously (16). Three to five chambers were used in each treatment. Washed cell suspensions (10^7-10^8 cells/ml) in respectivebuffers were added to each chamber and exposed to an in situ estuarine environment. The effect of montmorillonite and illite on S. faecalis MC-5 survival was also determined as described previously (16).

3. Cell Injury: Experimental procedures to detect injury or death of *S. faecalis* MC-5 populations were similar as described by Bissonnette et. al. (4): Immediately after suspending the chambers in the Rhode River, 0.1 ml of *S. faecalis* was withdrawn from each chamber with a 1 ml syringe and designated as the 0 hr. sample. Other samples were taken from the chambers at 6, 8, 24, and 48 hr. of exposure to the estuarine water. Enumeration of *S. faecalis* was done using both types of buffer (phosphate and gelatin phosphate) and two types of media. Azide dextrose agar (DIFCO) was used as a selective medium and trypticase soy agar (TSA) was used as a non-selective medium. Samples were enumerated using the spread plate procedure. Plates were incubated for 24 hr. at 37 C. All platings were done in triplicate.

To determine whether *S. faecalis* MC-5 cells are injured by environmental stress in the estuary, and whether injured cells have the capability to repair non-lethal injury was also tested as described by Bissonnette et. al. (4). A 4 ml cell suspension was taken immediately after immersing the chambers in the Rhode River and inoculated into 36 ml of trypticase soy broth (TSB). This sample was designated 0 hr, Day 0. A 0.1 ml sample was taken from the 36 ml of TSB every 20 min. for the first 2 hr, and every hr for the next four hrs, and serially diluted in standard phosphate buffer. The 36 ml of tryptic soy broth was incubated at 37 C between samples. All platings were done in triplicate on both azide dextrose agar (ADA) and on trypticase soy yeast agar (TSY) using spread plate procedure (4). Trypticase soy yeast agar consisted of trypticase soy agar, 0.5% dextrose, and 0.3% yeast extract. After the chambers were exposed in the Rhode River for 48 hr, a second 4 ml cell suspension was removed and inoculated into 36 ml of new TSB and treated similarly to that of the first day.

4. Data analysis: The survival of S. faecalis was also estimated by measuring simultaneously several ecological variables in the Rhode River. Two statistical analyses were performed on all the data. (i) Two variable linear regression, based on the relationship between two variables by using 7-day observations for each variable by a linear least-squares regression. A correlation coefficient (r) for each pair of variables were calculated. (ii) Multiple linear regression was also used to investigate the combined effects of several variables on S. faecalis as described in detail (16).

RESULTS

Water Flow

The pattern of water flow from the study sites changed seasonally (Table 2). Daily mean water flow at all seven basins ranged from a high of 8.32×10^6 l/day at basin 101 to a low of 0.06×10^6 l/day at basin 107 in August. Water flowed through all weirs during the entire water year 1974-75. Seasonal variations in water flow occurred. Flow was relatively low in May, June, August and November months. Water discharge was proportional to the size of the basin or the amount of precipitation which had fallen prior to the day of sample collection. The highest water discharge was recorded from the largest basins,101,102 and 103.

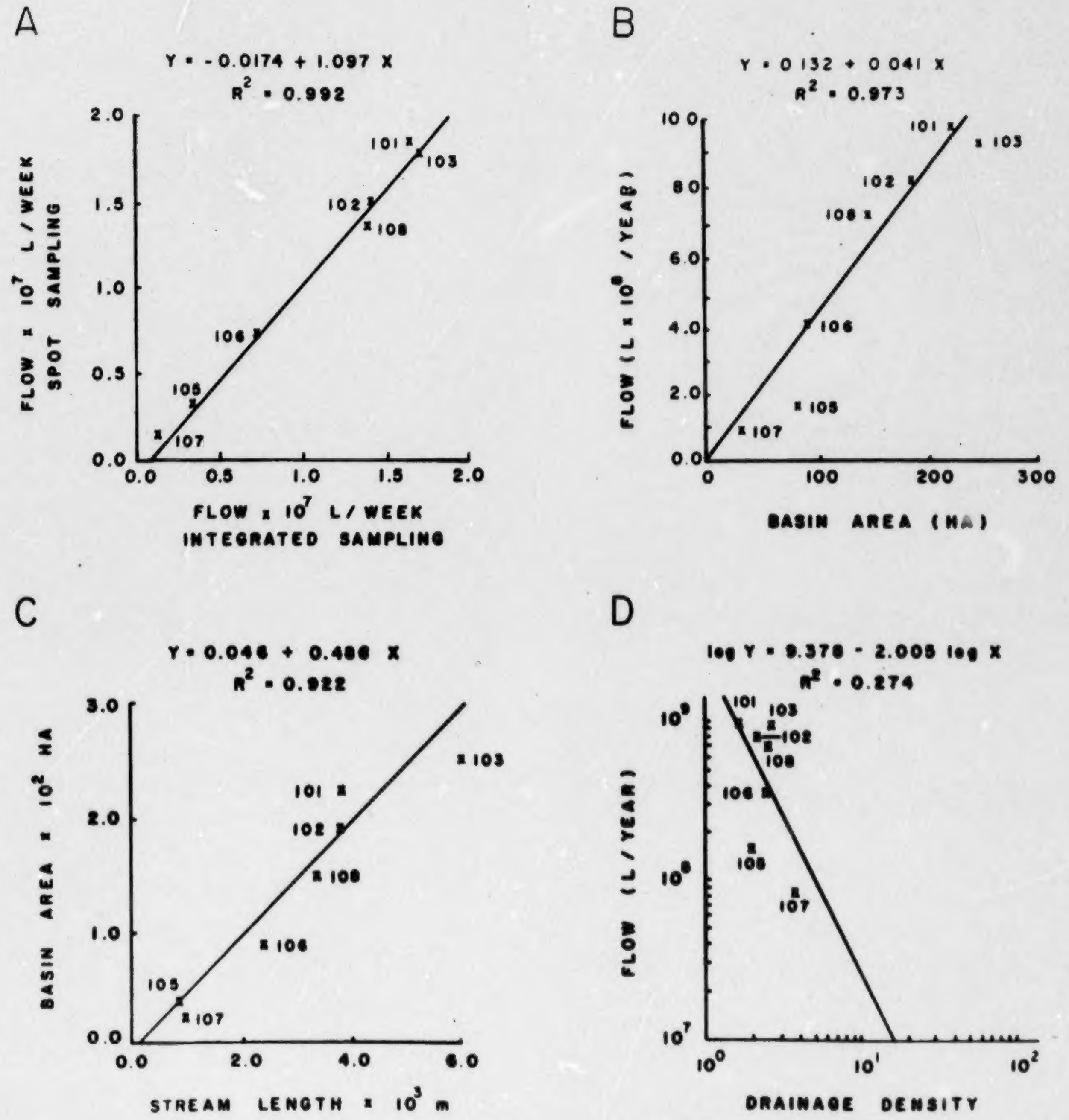
The average weekly water discharge for the entire year was calculated from one spot sample taken each week, and calculating the flow for the entire week, adding up individual weekly values and dividing them by the total number of weeks samples were taken. In average a total of 39 to 48 samples were collected per basin. The average weekly water discharge ranged from 1.87×10^7 l as high at basin 101 to 0.16×10^7 l as low at basin 107. The water discharge at the other basins were 1.83 x 10^7 1 at 103, 1.53 x 10^7 1 at 102, 1.40 x 10^7 1 at 108, 0.75 x 10^7 1 at 106, and 0.31 x 10^7 1 at 105 (Fig. 2a). Throughout this range the calculated flow, obtained from spot samples, and the integrated flow, determined by continuous recording discharge values correlated linearly (Fig. 2/a). A least squares regression analysis gave the best fit of the data: y (Flow L x 10^7 week^{-1} of spot samples) = -0.017 + 1.09 x (Flow L x 10^7 week^{-1} of integrated samples). The coefficient of variation was R^2 = 0.992 significant at the 99.9% probability level.

The same relationship existed for yearly total discharge of both spot and integrated water flow. Yearly discharge ranged from 9.73 to 7.28 x 10^8 1 year^{-1} at high water discharging basins such as 101, 102, 103 and 108 and 0.84 to 0.62 x 10^8 1 year^{-1} at low discharging basins 107, 105 and 106 respectively. The best fit of the data gave the following equation: Y (flow x 10^8 1 year^{-1} of spot samples) = -0.0982 x 10^8 + (1.098 x 10^8) X (flow x 10^8 1 year^{-1} of integrated flow). The coefficient of determination (R^2) for these variables was 0.992, significant at the 99.9% probability level.

Water flow was also compared with the size of basin and the length of the stream for each of the 7 basins. Basin sizes ranged from 28 to 254 ha. Characteristics of these basins have been described in detail. The annual water discharge and the basin area were linearly and positively correlated (Fig. 2/b). A least squares regression equation gave the best fit of the data: Y (flow L x 10^8 year^{-1}) = 0.132 + 0.041 X (basin size ha^{-1}) and a coefficient of variations of R^2 = 0.973 that was significant at the 99% probability level.

Basin size and stream length were also linearly and positively correlated

Fig. 2. Regression analyses of water flow and basin characteristics. Fig. 2/a. Linear relationship between flow of spot samples and flow of integrated samples. Slope: 1.097, intercept -0.0174, and coefficient of variation 0.992. Fig. 2/b. Linear relationship between yearly flow and basin area. Slope: 0.041, intercept 0.132, and coefficient of variation 0.973. Fig. 2/c. Linear relationship between basin area and stream length. Slope: 0.486, intercept 0.046, and coefficient of variation 0.922. Fig. 2/d. Linear relationship between yearly flow and drainage density. Slope: -2.005, intercept 9.378, and a coefficient of variations 0.274. Numbers 101 to 108 on each graph refer to the designated subwatershed basins.


A
Y = -0.0174 + 1.097 X
R² = 0.992
FLOW x 10⁷ L / WEEK
SPOT SAMPLING
FLOW x 10⁷ L / WEEK
INTEGRATED SAMPLING
0.0
0.5
1.0
1.5
2.0
101
102
103
105
106
107
108
B
Y = 0.132 + 0.041 X
R² = 0.973
FLOW (L x 10⁸ / YEAR)
BASIN AREA (HA)
0.0
2.0
4.0
6.0
8.0
10.0
0
100
200
300
101
102
103
105
106
107
108
C
Y = 0.046 + 0.486 X
R² = 0.922
BASIN AREA x 10² HA
STREAM LENGTH x 10³ m
0.0
1.0
2.0
3.0
0.0
2.0
4.0
6.0
101
102
103
105
106
107
108
D
log Y = 9.378 - 2.005 log X
R² = 0.274
FLOW (L / YEAR)
DRAINAGE DENSITY
10⁷
10⁸
10⁹
10⁰
10¹
10²
101
102
103
105
106
107
108

(Fig. 2/c). A least squares regression equation of the data gave the best fit: Y (basin size ha^{-2}) = 0.046 + 0.486 X (stream length m^{-3}). The coefficient of variation was $R^2 = 0.922$,statistically significant at 99.9% probability level. However, annual water discharge appears to be inversely proportional to drainage density [stream length (m) divided be the drainage basin area (m^2)] (26) (Fig. 2/d). A least squares regression equation gave the following relationship: log Y (flow L x 10^8 $year^{-1}$) = 9.378 - 2.005 log X (drainage density). The coefficient of variations was $R^2 = 0.274$ which was statistically not significant at 95% probability level.

Fecal Coliform Concentrations

FC concentrations were lowest during winter and fall and highest during summer (Table 5). The range of FC concentrations were very wide however, including low and high values in all seasons. The range of FC seasonal mean concentrations were as follows: winter 153 to 699 FC 100 ml^{-1}; spring 238 to 575 FC 100 ml^{-1}; summer 824 to 1239 FC 100 ml^{-1}; and fall 164 to 416 FC 100 ml^{-1} respectively.

A one way analysis of variance was used to test whether there was a difference in FC concentrations between seasons (Table 6). It appeared that FC concentrations were significantly higher in summer at most weirs (Tables 5 and 6). No detectable differences existed,however, in FC concentrations between winter, spring and fall seasons. The yearly mean FC concentrations ranged from 387 to 734 FC 100 ml^{-1} at the various basins (Table 5). The standard deviation was equal to or greater than the mean in most cases.

A Paired t-test was also used to distinguish differences in FC concentrations between basins (Table 7). This analysis indicated that FC concentrations from basin 106 were significantly different than those

Table 5: Mean Fecal Coliform concentration in water runoff from seven Rhode River basins.

		FC concentration/100 ml		
Basin	Season	Mean	±S.D.	Range
101	Winter	286	354	11 - 1100
	Spring	575	870	4 - 2400
	Summer	1125	1079	7 - 2400
	Fall	219	264	10 - 960
	Year	581	821	4 - 2400
102	Winter	348	332	43 - 1100
	Spring	344	645	3 - 2400
	Summer	1189	1103	3 - 2400
	Fall	345	566	50 - 2200
	Year	561	800	3 - 2400
103	Winter	409	818	28 - 2400
	Spring	245	653	3 - 2400
	Summer	1003	1116	4 - 2400
	Fall	288	668	20 - 2500
	Year	472	851	4 - 2500
105	Winter	173	151	15 - 460
	Spring	314	641	4 - 2400
	Summer	1136	1055	3 - 2400
	Fall	308	297	35 - 1000
	Year	523	766	3 - 2400
106	Winter	699	815	210 - 2400
	Spring	565	827	43 - 2400
	Summer	1239	1123	3 - 2400
	Fall	416	306	140 - 1200
	Year	734	862	3 - 2400
107	Winter	153	384	3 - 1100
	Spring	238	661	3 - 2400
	Summer	1108	1100	3 - 2400
	Fall	185	353	3 - 1200
	Year	450	809	3 - 2400
108	Winter	154	150	20 - 460
	Spring	333	688	3 - 2400
	Summer	824	969	4 - 2400
	Fall	164	133	18 - 500
	Year	387	668	3 - 2400
All Weirs	Winter	310	493	3 - 2400
	Spring	373	702	3 - 2400
	Summer	1090	1048	3 - 2400
	Fall	276	404	3 - 2500
	Year	529	798	3 - 2500

from basins 102, 103 and 105. Additionally, FC concentrations from basin 102 were different than those from basin 107 and FC concentrations from basin 103 were different than those from basin 105. No difference was found in FC concentrations between other basins.

Table 6. Estimation of differences in fecal coliform concentrations in water runoff between seasons using one way analysis of variance.

	Basin							
Seasons	101	102	103	105	106	107	108	All Basins
	F - values							
winter vs spring	0.87	0.01	0.25	0.31	0.12	0.05	0.57	0.34
winter vs summer	4.99*	4.83*	1.62	5.62*	1.25	5.50*	4.16	26.68**
winter vs fall	0.09	0.00	0.13	1.24	1.28	0.03	0.02	0.21
spring vs summer	2.05	5.57*	4.28	5.76*	3.03	5.96*	2.21	28.96**
spring vs fall	1.84	0.00	0.02	0.00	0.37	0.06	0.75	1.30
summer vs fall	7.99**	5.92*	3.76	7.42*	6.50*	8.28**	5.91*	47.16**
All seasons	3.65*	3.94*	2.10	4.96**	2.46	5.02**	3.08*	23.08**

Fecal Coliform Discharge

Although FC concentrations and FC discharge appear to follow the general trend, the calculation of total FC discharge is necessary to obtain meaningful data which can be used for estimating FC discharge from each basin. The total FC discharge ranged from 60 x 10^{10} to 876 x 10^{10} FC $year^{-1}$ depending on basin (Table 8). The lowest FC discharge was estimated from basin 107 and the largest from basin 101. In general when monthly FC discharge was high at one basin it was high at all other basins. The FC discharge values for March and July are comparatively high. This is due to the fact that samples were collected during storm events of significant size, which inflated the flow rate estimates and FC concentration. The highest monthly FC discharge, thus,occurred in the summer and the lowest in the fall and winter.

Table 7. Estimation of differences in fecal coliform concentrations in water runoff between basins using the Paired t-test.

	Basins						
Basins	101	102	103	105	106	107	108
	t-value						
101	-	0.02	1.18	0.61	1.55	1.26	0.91
102	-	-	0.51	0.56	2.21*	2.81*	1.68
103	-	-	-	2.37*	3.65**	0.61	0.60
105	-	-	-	-	3.02**	0.32	1.37
106	-	-	-	-	-	0.15	0.90
107	-	-	-	-	-	-	0.24

Fecal coliform yearly discharge depended on the size of basin (Fig. 3/a). The larger sized basins discharged more FC bacteria year^{-1} than smaller basins (Table 8). A least squares regression analysis gave a linear positive relationship: Y (FC x 10^{12} discharged year^{-1}) = 0.279 + 0.032 X (basin size, ha). The coefficient of variation was $R^2 = 0.900$ significant at 95% probability level.

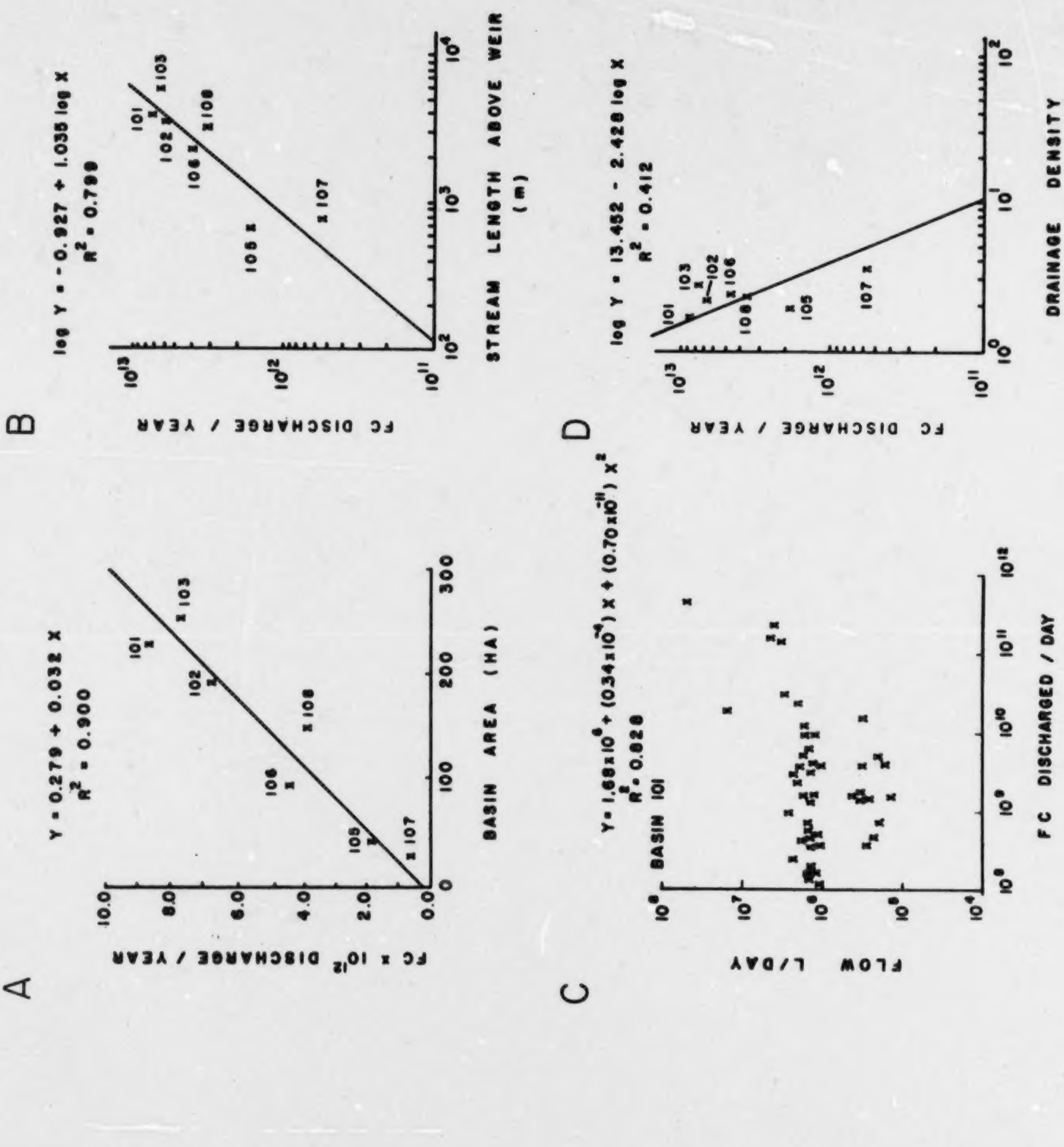
A linear positive relationship also existed between FC discharge and

Table 8: Fecal coliform monthly discharge from seven Rhode River basins.

Months	Basins						
	101	102	103	105	106	107	108
1974-75	FC x 10^{10} discharged/month						
December	24.69	152.36	28.42	-	-	3.97	53.67
January	9.24	13.88	1.34	3.19	65.35	0.02	7.12
February	4.55	7.72	8.05	0.91	10.49	0.29	4.71
March	205.60	108.32	126.73	8.08	90.55	9.64	44.82
April	14.86	20.69	97.58	5.04	8.35	1.00	2.55
May	0.54	0.18	0.29	0.24	8.39	0.11	0.11
June	18.43	13.75	102.23	0.66	4.53	2.45	9.95
July	549.32	283.60	343.33	106.63	212.22	41.27	225.79
August	30.22	47.14	39.95	27.57	14.50	1.47	6.79
September	5.80	6.66	6.42	16.70	3.95	0.32	4.62
October	7.23	7.10	4.91	12.10	11.16	-*	6.61
November	5.87	6.87	3.54	3.11	4.90	-*	2.74
Annual	876.36	668.28	762.79	184.23	434.39	60.49	369.68

* = weir inoperable

Fig. 3. Regression analyses of Fecal Coliform (FC) yearly discharge, basin characteristics and water discharge. Fig. 3/a. Linear relationship between FC discharge and basin area. Slope: 0.032, intercept 0.279, and coefficient of determination 0.900. Fig. 3/b. Linear relationship between FC discharge and stream length. Slope: 1035, intercept -0.927, and coefficient of variation 0.799. Fig. 3/c. Parabolic relationship between water flow and FC discharge. Intercept 1.68×10^6, coefficients a_1 0.34×10^{-4}, a_2 0.70×10^{-11}, and coefficient of variations 0.828. Fig. 3/d. Linear relationship between FC discharge and drainage density. Slope -2.428, intercept 13.45 and coefficient of variation 0.412. Numbers 101 to 108 on each graph refer to the designated subwatershed basins.


A
Y = 0.279 + 0.032 X
R² = 0.900
FC x 10¹² DISCHARGE / YEAR
10.0
8.0
6.0
4.0
2.0
0.0
101
102
103
106
108
105
107
0
100
200
300
BASIN AREA (HA)
B
log Y = -0.927 + 1.035 log X
R² = 0.799
FC DISCHARGE / YEAR
10¹³
10¹²
10¹¹
101
102
103
106
108
105
107
10²
10³
10⁴
STREAM LENGTH ABOVE WEIR
(m)
C
Y = 1.68x10⁶ + (0.34x10⁻⁴) X + (0.70x10⁻¹¹) X²
R² = 0.828
BASIN 101
FLOW L/DAY
10⁸
10⁷
10⁶
10⁵
10⁴
10⁸
10⁹
10¹⁰
10¹¹
10¹²
FC DISCHARGED / DAY
D
log Y = 13.452 - 2.428 log X
R² = 0.412
FC DISCHARGE / YEAR
10¹³
10¹²
10¹¹
101
103
102
106
108
105
107
10⁰
10¹
10²
DRAINAGE DENSITY

stream length (Fig. 3/b). A least squares regression analysis gave the relationship: log Y (FC x 10^{12} discharged $year^{-1}$) = - 0.927 + 1.035 log X (stream length m^{-3}). The coefficient of determination was $R^2 = 0.799$,

significant at the 95% probability level. Obviously larger basins have longer streams and if FC discharge is expressed based on either basin size or on stream length the relationships are almost the same.

Water flow carried FC bacteria from the watershed into the Rhode River estuarine waters (15). Several investigators reported that the degree of discharge of sediments and nutrients depends on rate of water discharge (6, 13). Evans and Owens (12) also reported that the rate of water flow is also related to the bacterial discharge. These investigators (12) studied a 0.7 ha area and investigated the relationship between the soil bacteria and land-drainage water discharge. We found a similar relationship between FC discharge and water discharge. FC discharge could be related to flow rate by a parabolic regression equation. Increased water flow increased FC discharge proportionally at an exponential rate from basin 102 (Fig. 3/c). Fecal coliform discharge was little affected until water flow increased to about 2 x 10^6 1/day. After this flow rate FC discharge increased rapidly with increasing water flow. This indicates that, as the water flow increases, its importance in determining the rate of FC discharge increases at an exponential rate. This relationship is expressed by the equation $Y = 1.68 \times 10^6 + (0.34 \times 10^{-4}) X + (0.70 \times 10^{-11}) X^2$ in which X = flow 1 x 10^6 day^{-1} and Y = FC x 10^9 discharged day^{-1}. The coefficient of determination was $R^2 = 0.828$.

The relationship between water flow and FC discharge was analyzed for all seasons and for the year at each basin (Table 9). The coefficients of determination (R^2) were obtained for the data. A two variable parabolic regression

Table 9. Coefficients of determination for seasonal water discharge (Y)[a] against seasonal FC discharge (X)[b] from seven Rhode River basins using two variable parabolic regression equation.

Seasons 1974-75	Basins						
	101	102	103	105	106	107	108
	Coefficient of Determination (R^2)						
Winter	0.98*	0.99*	0.15	0.97*	0.97*	0.83*	0.99*
Spring	0.79*	0.38	0.91*	0.52*	0.57*	0.39	0.53*
Summer	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*
Fall	0.40	0.51*	0.74*	0.51*	0.72*	0.99*	0.36
Annual	0.83*	0.75*	0.53*	0.84*	0.88*	0.76*	0.65*
N[c]	48	47	46	46	46	39	48

a = Flow L x 10^6/day; b = FC x 10^6 discharged/day; c = number of weeks sampled during the year

Table 10. Estimation of difference in Fecal coliform discharge/ha day between basins using the paired t-test.

Basin	Basin						
	101	102	103	105	106	107	108
	t-value						
101	-	0.08	1.19	0.16	1.65	1.74	1.50
102	-	-	1.04	0.44	1.53	2.05*	1.49
103	-	-	-	0.64	1.57	1.19	0.26
105	-	-	-	-	1.43	0.96	1.11
106	-	-	-	-	-	1.87	2.38*
107	-	-	-	-	-	-	0.76

analysis indicated that 83-99% of the variation in FC discharge can be explained with water discharge during the spring and summer and 51-79% during fall and winter. Yearly R^2 values ranged from 0.53 to 0.88 and were significant at the 95% probability level.

Fecal coliform discharge per unit watershed area was also calculated. FC discharge from the 7 basins were as follows: 3.9 x 10^{10}/ha year at basin 101; 3.5 x 10^{10}/ha year at basin 102; 3.0 x 10^{10}ha year at basin 103; 4.9 x 10^{10}/ha year at basin 105; 4.6 x 10^{10}/ha year at basin 106; 2.1 x 10^{10}/ha year at basin 107; and 2.4 x 10^{10}/ha year at basin 108. The variation in FC discharge/ha year was much smaller from the various basins than the FC discharge/year. FC discharge/ha year was the highest (4.6 and 4.9 x 10^{10}) from basins 105 and 106 and the lowest (2.1 and 2.4 x 10^{10}) from basins 107 and 108. In contrast, when FC discharge was calculated only on the yearly basis (FC discharge/year) the highest discharge was 8.7 x 10^{12} from basin 101 and the lowest 0.6 x 10^{12} from basin 107 (Table 8).

The paired t-test was also used to distinguish differences in FC discharge/ha year between basins (Table 10). The results indicate significant difference between basins 102 and 107, and 106 and 108. However, no differences were found between the other basins. Similarly, no differences were found in FC discharge/ha year between basins using one-way analysis of variance (Table 11).

When the FC discharge/year per unit length of stream was calculated, results are very similar to those expressed as FC discharge/ha year (Table 12). The FC discharge per unit stream length was as follows: 2.35 x 10^{12} FC/Km year at basin 101; 1.67 x 10^{12} FC/Km year at basin 102; 1.12 x 10^{12} FC/Km year at basin 103; 2.56 x 10^{12} FC/Km year at basin 105; 1.87 x 10^{12} FC/Km year at

Table 11. Estimation of difference in fecal coliform discharge/ha day between seasons using one way analysis of variance.

Seasons	101	102	103	105	106	107	108
Winter vs spring	1.48	0.36	0.27	0.54	0.06	0.11	0.44
Winter vs summer	0.90	0.06	1.33	0.62	0.11	0.89	0.41
Winter vs fall	0.05	1.12	0.02	0.01	1.75	0.06	1.59
Spring vs summer	0.46	0.75	1.34	1.04	0.39	1.10	1.07
Spring vs fall	2.13	0.40	0.49	0.78	1.80	0.15	0.99
Summer vs fall	1.25	1.57	2.26	1.16	1.20	0.50	1.45
All seasons	0.91	0.68	1.50	0.93	0.59	0.78	0.96

Column headings: Basins (101–108); values are F-values.

basin 106; 0.59 x 10^{12} FC/Km year at basin 107; and 1.01 x 10^{12} FC/Km year at basin 108 respectively. Basin 105 discharged FC at the highest rate, discharging4.3 times more FC/Km than did the lowest FC discharging basin, 107. Therefore, it is better to express FC discharge per unit area than FC discharge per unit length of stream.

Ongley (30) indicated that drainage density can be used as a characterization of watersheds in estimating loading rates into receiving waters. In the Rhode River subbasins, drainage density and FC discharge do not appear closely related (Fig 3/d). A least squares regression analysis gave the following relationship, log Y (FC x 10^{12} discharge/year) = 13.45 - 2.48 log X (drainage density). The coefficient of variation was R^2 = 0.415 and it was not significant at the 95% probability level.

Table 12. Fecal coliform discharged per unit stream length from seven Rhode River basins.

Basin	FC x 10^2 Discharged/year	Stream Length Km	FC x 10^{12} Discharge/Km
101	8.7	3.7	2.3
102	6.7	4.0	1.7
103	7.6	6.8	1.1
105	1.8	0.7	2.5
106	4.3	2.3	1.9
107	0.6	1.0	0.6
108	3.7	3.6	1.0

Coliform Discharge - Land Use Relationship

The proportion of yearly FC discharge from 3 land use types was determined by applying a statistical model which relates land use to FC discharge (Table 13). From pasture the discharge was 89 x 10^9 FC/ha year, from forest 22.4 x 10^9 FC/ha year and from cultivated land 19.8 x 10^9 FC/ha year. The FC discharge rates from each land use type varied seasonally. Pasture discharge ranged from 0.1 to 62.1 x 10^9 FC/season; forest discharge ranged from -1.7 to 15.3 x 10^9 FC/season; and cultivated land discharge ranged from -8.6 to 23.7 x 10^9 FC/season. The pattern of FC discharge from pasture and forest was similar. FC discharge was the highest in summer followed by a decreased magnitude in spring, winter and fall. In contrast, the cultivated land discharged the highest number of cells in winter. This is probably due to the practice of some farmers spreading manure on the soil during the winter months.

Table 13: Predicted yearly and seasonal fecal coliform discharge from pasture, forest and cultivated areas from seven basins.

Seasons	Pasture	Forest	Cultivated
	FC x 10^9 discharged/ha		
Winter	0.8	-1.7	23.7
Spring	26.0	8.2	- 8.6
Summer	62.1	15.3	1.9
Fall	0.1	0.6	2.8
Year	89.0	22.4	19.8

Negative discharge values, which appeared in the forest area in winter and in cultivated land in spring were interpreted to mean that a particular land use served as depository rather than as a source of FC cells. However, since these negative values are small in comparison to FC discharge in other seasons, they may indicate that FC discharge was either zero or very low.

Fecal Streptococci, Concentration

Fecal Streptococci (FS) concentrations in water runoff ranged from 680-1701 FS/100ml for the year (Table 14). The highest FS concentrations were estimated from the smallest basin 107 and the lowest FS concentration from the largest basin 103. The average yearly FS concentrations for all basins were 1067 FS/100ml. The ratio of the standard deviation to the sample mean was relatively large in most cases. Fecal Streptococci concentrations were low during winter and spring and high during summer and fall (Table 14). The range of seasonal mean FS concentrations were as follows: winter 15-724 FS/100 ml; spring 69 to 560 FS/100ml; summer 1441-4161/100ml; and fall 656-1038 FS/100ml respectively. The one way analysis of variance was used to estimate differences in FS concentrations between seasons (Table 15). It appeared that FS concentrations were significantly higher and different in summer from those of other seasons (Tables 14 and 15). However, basin 107 was an exception, where no detectable difference in FS concentrations was found between seasons.

A paired t-test was used to estimate differences in FS concentration between basins (Table 16). It appeared that FS concentrations from basin 103 were significantly lower and different than those from basins 101, 102, 105 and 106 (Tables 14 and 16). Fecal

Table 14. Mean Fecal Streptococcus concentrations in water runoff from seven Rhode River basins.

Basin	Season	FS concentration/100ml		
		Mean	±S.D.	Range
101	winter	724	1122	15 - 2400
	spring	541	873	9 - 2400
	summer	2005	679	460 - 2800
	fall	656	928	50 - 3600
	year	1035	1052	9 - 3600
102	winter	360	502	23 - 1100
	spring	159	311	3 - 1100
	summer	2250	902	1100 - 3400
	fall	1038	1700	70 - 6600
	year	1047	1353	3 - 6600
103	winter	181	193	23 - 460
	spring	69	126	4 - 460
	summer	1441	892	240 - 2400
	fall	801	1582	70 - 6000
	year	680	1126	4 - 6000
105	winter	74	112	7 - 240
	spring	300	461	4 - 1100
	summer	2139	1061	210 - 4000
	fall	869	1340	25 - 5100
	year	1007	1240	4 - 5100
106	winter	702	476	150 - 1100
	spring	560	697	11 - 2400
	summer	2058	759	700 - 3300
	fall	831	1423	110 - 5500
	year	1108	1144	11 - 5500
107	winter	15	8	3 - 21
	spring	499	853	4 - 2400
	summer	4161	7215	1100 - 28000
	fall	961	1296	30 - 4600
	year	1701	4280	3 - 28000
108	winter	67	116	3 - 240
	spring	248	652	9 - 2400
	summer	1835	632	1100 - 2400
	fall	777	1282	25 - 4900
	year	871	1086	3 - 4900
All weirs	winter	303	530	3 - 2400
	spring	339	630	3 - 2400
	summer	2289	2898	210 - 28000
	fall	847	1342	25 - 6600
	year	1067	1956	3 - 28000

Table 15. Estimation of differences in Fecal Streptococci concentrations in water runoff between seasons using one way analysis of variance.

Seasons	Basins 101	102	103	105	106	107	108
	F-values						
Winter vs Spring	0.12	0.96	1.91	0.91	0.14	1.23	0.29
Winter vs summer	8.08*	15.46**	7.49*	14.44**	11.10**	1.26	29.66**
Winter vs fall	0.01	0.59	0.58	1.37	0.03	2.03	1.17
Spring vs summer	22.78**	62.08**	30.24**	32.87**	27.46**	3.30	39.72**
Spring vs fall	0.10	3.36	2.76	2.10	0.37	1.15	1.76
Summer vs fall	17.88**	4.83*	1.41	7.17*	7.52*	2.48	7.12*
All seasons	7.97**	8.20**	3.99*	9.29**	5.95**	2.31	8.69**

Table 16. Estimation of differences in Fecal Streptococci concentrations in water runoff between basins using the paired t-test.

Basins	Basins 101	102	103	105	106	107	108
	t-test						
101	-	0.34	2.40*	0.23	0.64	1.07	1.58
102	-	-	4.04**	0.25	0.54	1.03	1.85
103	-	-	-	3.05**	3.79**	1.51	1.08
105	-	-	-	-	0.84	1.23	1.11
106	-	-	-	-	-	0.92	2.29*
107	-	-	-	-	-	-	1.34
108	-	-	-	-	-	-	-

Streptococci concentrations were also significantly lower at basin 106 than those at basin 108. No difference was found in FS concentrations between basin 107 and any other basin. The usually high FS concentrations at weir 107 may be due to an exceptionally high FS (28,000/100ml) concentration on day 223 of 1975.

Fecal Streptococci Discharge

The total yearly FS discharge ranged from 0.9×10^{12} to 11.2×10^{12} FS/year depending on basin (Table 17). The highest FS discharge was estimated from basin 101 and the lowest from basin 107. Water discharge was the highest during the summer shown in Table 2. These high water flow values corresponded closely with the high FS discharge levels from all basins. Thus, the highest FS discharge occurred in the summer and the lowest in the fall and winter (Table 17).

Fecal Streptococci discharge (Table 17 and Fig. 4/a) and FC discharge (Table 8 and Fig. 3/a) depended on the size of basin. The larger basins discharged more bacteria per year than the smaller basins (Fig. 4/a). A least squares regression analysis gave a linear positive relationship: Y (FS x 10^{12} discharged/year = 0.246 + 0.034 X (basin size/ha). The coefficient of variation was $R^2 = 0.772$, significant at 95% probability level.

A linear positive relationship existed between FS discharge and stream length (Fig. 4/b). A least squares regression analysis gave the relationship: log Y (FS x 10^{12} discharged/year) = 9.44 + 0.94 log X (stream length/m). The coefficient of determination was $R^2 = 0.717$, significant at 95% probability level.

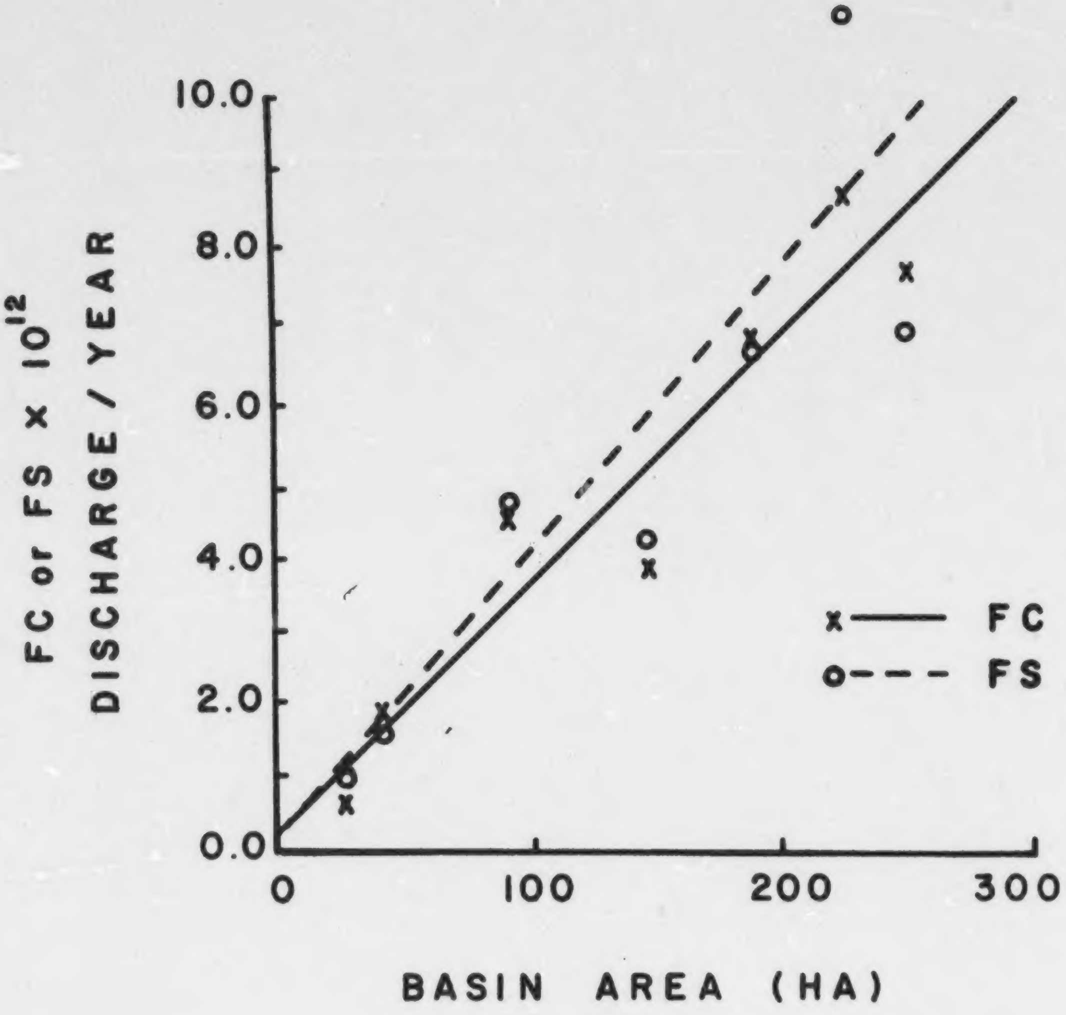
Table 17. Fecal Streptococci monthly and annual discharge from seven Rhode River basins.

Months 74-75	101	102	103	105	106	107	108
				FS x 10^{10} discharge/month			
December*	51.23	20.22	10.86	0.54	13.54	0.09	2.59
January*	51.23	20.22	10.86	0.54	13.54	0.09	2.59
February	46.28	18.26	9.81	0.49	12.23	0.08	2.34
March	128.10	47.52	23.46	19.98	37.70	9.35	3.44
April	8.24	0.92	0.90	0.23	5.94	0.77	3.02
May	27.51	7.49	4.22	3.30	40.66	3.33	20.06
June	27.77	17.60	95.83	2.45	28.37	3.58	17.40
July	613.05	317.16	382.97	119.11	235.22	46.28	256.90
August	37.98	34.20	18.16	4.52	5.81	13.19	16.45
September	96.58	134.09	91.68	20.56	40.24	5.30	64.17
October	20.41	25.42	15.59	2.70	11.06	**	14.79
November	9.98	17.26	19.07	3.56	6.39	-	7.27
				FS x 10^{12} discharge/year			
Annual	11.18	6.60	6.83	1.78	4.51	0.93	4.11

* December and January values estimated from February water discharge values.
**Weir inoperable

Fig. 4. Regression analyses of Fecal Streptococci (FS) yearly discharge, basin characteristics and water discharge. Fig. 4/a. Linear relationship between FS discharge and basin area. Slope: 0.034, intercept 0.246, and coefficient of determination 0.772. Fig. 4/b. Linear relationship between FS discharge and stream length. Slope: 0.940, intercept 9.44 and coefficent of variation $R^2 = 0.717$. Fig. 4/c. Parabolic relationship between water flow and FS discharge. Intercept: 1.45×10^6, coefficients a_1 2.56×10^{-5}; a_2 2.13×10^{-17}; and coefficient of variations $R^2 = 0.921$. Fig. 4/d. Linear relationship between FS discharge and drainage density. Slope: -2.16, intercept 13.40 and coefficient of variations $R^2 = 0.393$. Numbers 101 to 108 on each graph refer to the designated subwatershed basins.

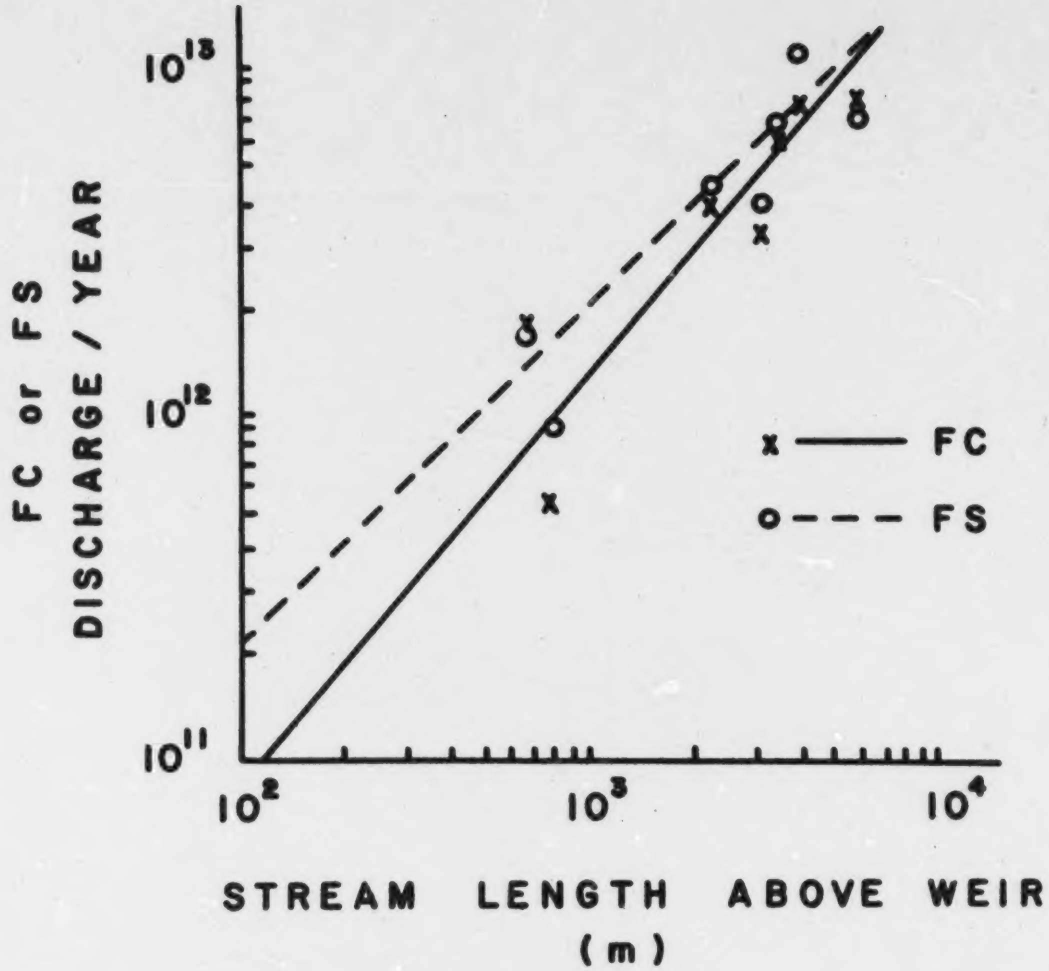
Fig. 4/a.



FC: $Y = 0.279 + 0.032\,X$
$R^2 = 0.900$

FS: $Y = 0.246 + 0.034\,X$
$R^2 = 0.772$

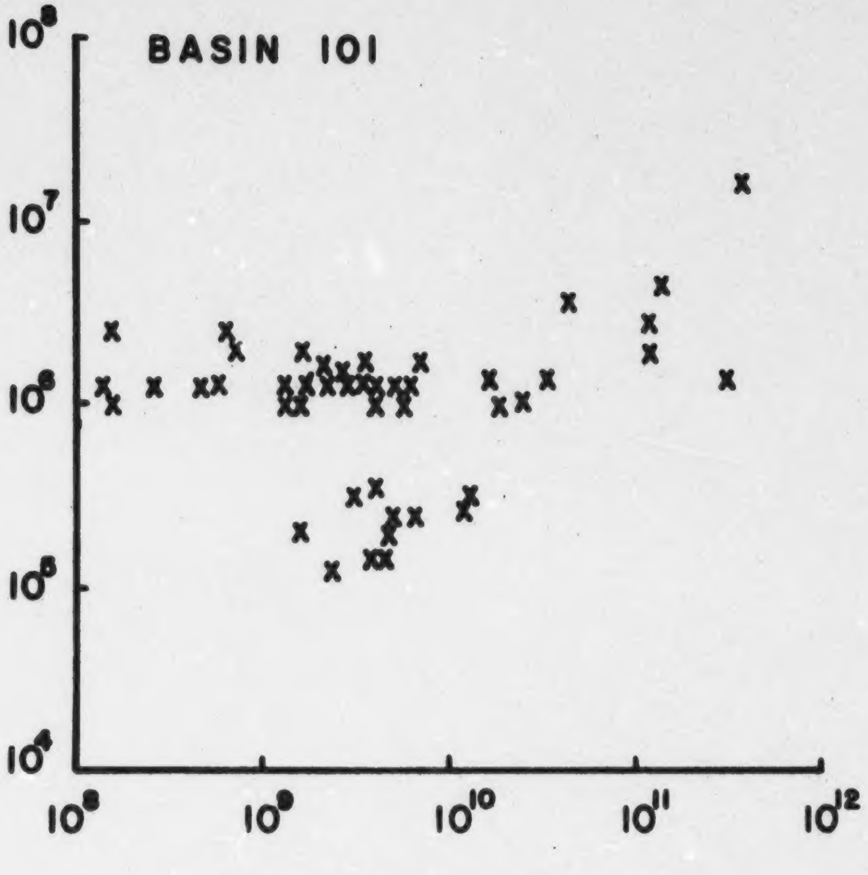
Fig. 4/b.



FC: $\log Y = 9.936 + 1.038 \log X$
$R^2 = 0.799$

FS: $\log Y = 9.440 + 0.942 \log X$
$R^2 = 0.717$

Fig. 4/c.

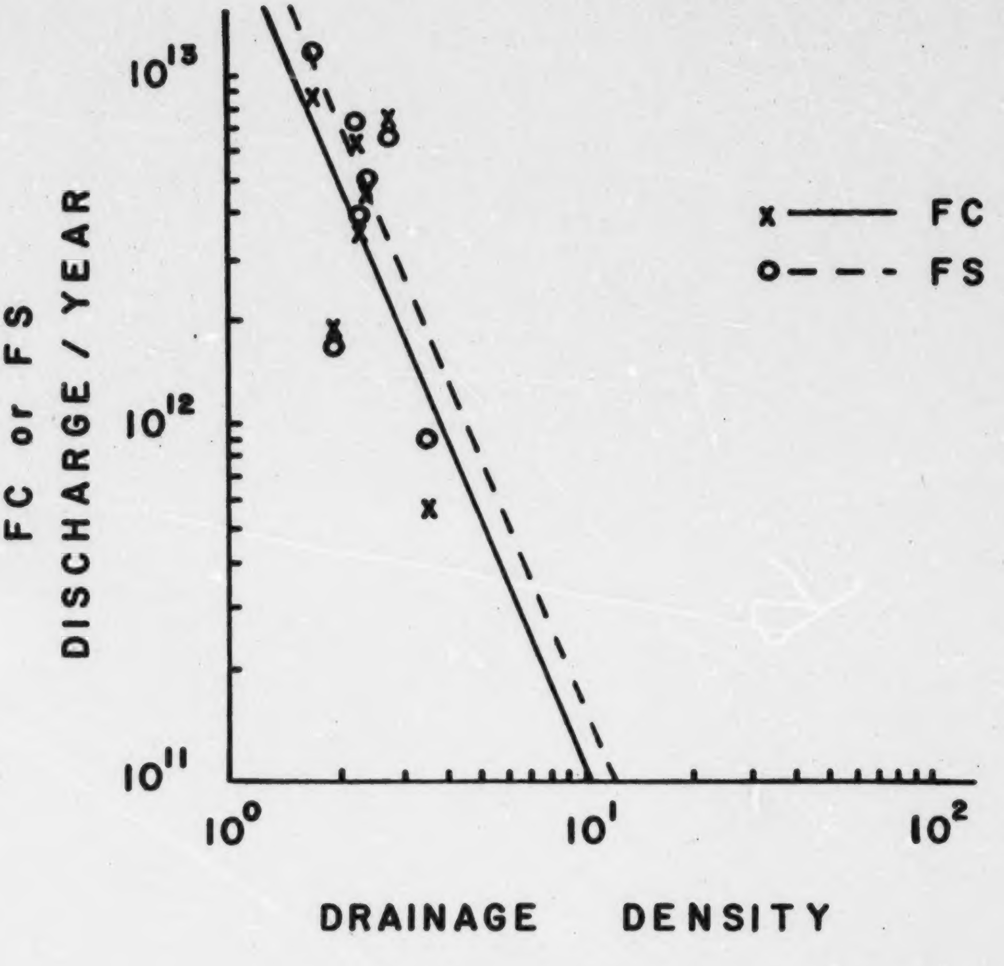


FS DISCHARGED / DAY

$$Y = 1.45 \times 10^6 + (2.56 \times 10^{-6}) X + (2.13 \times 10^{-17}) X^2$$

$$R^2 = 0.921$$

Fig. 4/d.



FC: $\log Y = 13.452 - 2.428 \log X$

$R^2 = 0.412$

FS: $\log Y = 13.400 - 2.160 \log X$

$R^2 = 0.393$

Drainage density and FS discharge do not appear closely related (Fig. 4/d). A least squares regression analysis gave the following relationship, log Y (FS x 10^{12} discharge/year) = 13.40 - 2.16 log X (drainage density). The coefficient of variation was $R^2 = 0.393$ and it was not significant at the 95% probability level. The above relationship is very similar that existing between FC discharge/year and drainage density (Fig. 3/d).

A parabolic regression equation was used to estimate the relationship between FS discharge and flow rate (Fig. 4/c). Increased water flow increased FS discharge proportionally at an exponential rate from basin 101. The best fit of the data is expressed by the equation Y (flow 1 x 10^6/day) = 1.45 x 10^6 + (2.56 x 10^{-5}) x (FS x 10^9 discharged/day) + (2.13 x 10^{-17}) X^2. The coefficient of determination was $R^2 = 0.921$.

The relationship between water flow and FS discharge was also analyzed for all seasons and for the year at the seven basins (Table 18). The coefficients of determination (R^2) are listed for the data: the two variable parabolic regression analysis indicated that 93 to 99% of the variation in FS discharge can be explained with water discharge during summer and 53 to 99% during the other seasons. Yearly R^2 values ranged from 0.63 to 0.95 and most values were significant at the 95% probability level.

Fecal Streptococci discharge per unit watershed area was also estimated. The yearly average FS discharge from the seven basins was 1.21 x 10^8/ha day. The yearly average FS discharge values ranged from a high of 1.54 x 10^8/ha year at basin 106 to a low of 8.81 x 10^7/ha year at basin 108. The seasonal average FS discharge/ha day were as follows: winter 2.57 x 10^7 FS/ha day; spring 5.50 x 10^7 FS/ha day; summer 2.6 x 10^8 FS/ha day; and fall 7.90 x 10^7 FS/ha day respectively. Summer FS discharge values were high at all basins (Table 17). A one way analysis of variance indicated no significan differences in FS discharge between any of the seasons (Table 19). Differences in FS discharge/ha day between basins was estimated using a paired t-test (Table 20). This analysis appeared to indicate significant differences only between FS discharge at basin 106 (highest FS discharge/ha day) and at basin 108 (lowest FS discharge/ha day) and no difference at all other basins.

Table 18. Coefficients of determination for seasonal water discharge (Y)[a] against seasonal Fecal Streptococci discharge (X)[b] from seven Rhode River basins using two variable parabolic regression equation.

Seasons 1974-75	Basins 101	102	103	105	106	107	108
	Coefficient of Determination (R^2)						
Winter	0.99*	0.25	0.41	0.99*	0.78	0.99*	0.79*
Spring	0.53*	0.46	0.70*	0.96*	0.98*	0.46	0.02
Summer	0.99*	0.99*	0.99*	0.99*	0.99*	0.93*	0.99*
Fall	0.49	0.54	0.07	0.34	0.16	0.99*	0.08
Annual	0.94*	0.63*	0.83*	0.95*	0.95*	0.78*	0.85*
N[c]	43	42	41	43	43	34	43

a = flow L x 10^6/day

b = FS x 10^6 discharged/day

c = number of weeks sampled during the year

Table 19. Estimation of difference in Fecal Streptococci discharge/ha day between seasons using one way analysis of variance.

Seasons	Basin 101	 102	 103	 105	 106	 107	 108
	F - values						
Winter vs spring	0.02	0.01	0.00	0.77	0.71	0.73	0.36
Winter vs summer	0.32	0.69	0.83	0.44	0.41	1.06	0.64
Winter vs fall	0.01	0.33	0.43	0.59	0.10	2.47	0.65
Spring vs summer	0.94	2.22	2.84	0.91	0.84	1.91	1.89
Spring vs fall	0.08	1.00	1.40	0.02	0.20	0.01	1.34
Summer vs fall	1.12	0.51	1.64	0.81	1.05	0.55	0.86
All seasons	0.75	0.97	1.70	0.70	0.74	1.12	1.10

Table 20. Estimation of difference in Fecal Streptococci discharge/ha day between basins using the paired t-test.

Basin	Basin 101	 102	 103	 105	 106	 107	 108
	t-value						
101	-	0.68	1.65	0.68	1.32	1.37	1.84
102	-	-	1.22	0.74	1.02	0.64	1.40
103	-	-	-	1.38	1.99	0.33	0.16
105	-	-	-	-	0.14	1.10	1.44
106	-	-	-	-	-	1.54	2.20*
107	-	-	-	-	-	-	0.29
108	-	-	-	-	-	-	-

Fecal Streptococci Discharge - Land Use Relationship

The statistical model was applied to estimate FS discharge values from 3 land uses (Table 21). From pasture the discharge was 15.11 x 10^{10} FS/ha year, from forest 0.95 x 10^{10} FS/ha year and from cultivated areas 1.67 x 10^{10} FS/ha year. The seasonal FS discharge rates were variable. Pasture had the highest FS discharge ranging from 0.67 to 7.6 FS/season; forest 0.3 to 1.29 x 10^{10} FS/season; and cultivated land 0.02 to 0.71 x 10^{10} FS/season. The highest FS discharge values occurred at all three land use during the summer and discharge values declined in the following order: winter, spring and fall. Considering the FS discharge values in each land use category, the model indicates that 85% of total FS discharge was derived from pasture, 10% from cultivated and 4% from forested areas.

Table 21. Predicted yearly and seasonal fecal streptococci discharge from pasture, forest and cultivated areas.

Seasons	Pasture	Forest	Cultivated
	FS x 10^{10} discharged/ha		
Winter	3.30	-0.30	-0.42
Spring	3.43	-0.38	0.02
Summer	7.60	1.29	0.71
Fall	0.67	0.48	0.48
Year	15.11	0.95	1.67

Identification - Confirmation of Indicator Bacteria

1. Total coliforms: coliform flora of water samples selected at random

were used to estimate Escherichia coli as % of total coliform population (Table 22). It appeared that total coliform population in water runoff consisted of numerous genera, such as E. coli, Enterobacter, Klebsiella, Citrobacter and unidentified organisms. The most numerous isolate was E. coli representing 29 to 74% of the total coliform population.

2. Fecal coliform: Bacterial colonies were also selected from the surface of the membrane filters to confirm the % of E. coli of FC bacterial flora. All randomly selected typical FC colonies were confirmed to be E. coli. Thus, FC is a better parameter assessing water quality than TC.

3. Fecal Streptococci: Confirmation of FS in randomly selected water samples were used to estimate S. faecalis biotypes as % of the fecal streptococci (FS) population (Table 23). It appeared that S. faecalis biotypes represented the largest streptococci population, ranging from 59 to 90% of TS flora. About 34% of TS population could not be identified. Streptococcus bovis and S. equinus represented a very low percent of the streptococci in the samples.

4. Salmonella: Water samples were analysed for the presence of Salmonella in runoff of seven Rhode River basins (see Tables in Appendix). Salmonella-like organisms were high in some samples (2400 MPN/ml) and low in other samples. High levels of Salmonella were estimated during spring and summer and low values in the fall and winter. The samples with large numbers of Salmonella also contained high numbers of FC and FS and occurred at times of high water discharge. However, out of many hundred samples only very few Salmonella-like isolates were confirmed as true Salmonella. Perhaps the enrichment procedure used and the size of samples were not appropriate for our purpose to detect these bacteria.

Table 22. Confirmation of bacterial species within the total coliform group in water samples taken between September and November 1975.

Basin	Bacterial Species						
	E. coli	Enterobacter	Klebsiella	Citrobacter	Unidentified	E. coli % of TC	No. Colonies tested
101	21	2	4	1	2	70	30
102	7	0	0	0	4	64	11
103	2	2	0	1	2	29	7
105	17	1	1	1	3	74	23
106	10	0	1	0	3	71	14
107	3	1	0	2	4	30	10
108	0	3	0	0	3	0	6
All basin	60	9	6	5	21	59	101

Table 23. Confirmation of bacterial species within the fecal streptococci in water samples taken between October 1975 and August 1976.

Basin	S. faecalis biotypes	% of total	S. bovis or S. equinus	% of total	Other FS	% of total	Total No. Colonies tested
101	18	72	1	4	6	24	25
102	74	63	5	4	38	32	117
103	8	62	2	15	3	23	13
105	84	56	1	1	65	43	150
106	9	90	1	10	0	0	10
107	12	86	2	14	0	0	14
108	40	59	4	06	24	35	68
Total	245	62	16	04	136	34	397

5. Total Aerobic Heterotrophic Population (TVC): The yearly mean TVC bacterial population in water runoff ranged from 30.5×10^3 TVC/ml to 364.9×10^3 TVC/ml (Table 24). The highest TVC concentrations were estimated in the runoff at basin 101 (yearly mean 204.8×10^3 TVC/ml) and the lowest concentration at basin 105 (yearly mean 55.2×10^3 TVC/ml). The seasonal mean bacterial concentrations in the runoff were as follows: winter 364.9×10^3 TVC/ml; spring 123.9×10^3 TVC/ml; summer 52.2×10^3 TVC/ml; and fall 30.5×10^3 TVC/ml respectively. The standard deviation to the sample mean was relatively large in most cases.

Survival and Injury of Fecal Streptococcus

1. Survival: the effect of physical parameters of estuarine water on *S. faecalis* MC-5 survival was determined. All simultaneously collected data was used as follows: log viable cell numbers as dependent variable and time, water temperature, dissolved oxygen (D.O.) and salinity as independent variables. The relationship between the above variables was estimated by regression analysis. It appeared that 60% of the variance in viable cell numbers was explained by the length of time ($R^2 = 0.593$) the cells were exposed to the estuary. This result is similarly reported by Faust et. al. (16) on *E. coli* MC-6 survival.

The effect of temperature on *S. faecalis* MC-5 survival was also examined (Fig. 5). During the course of study temperature ranged from 7 to 23 C (Table 25). A linear relationship existed between survival rate of bacteria and water temperature. The slope of decline in viable cell numbers was calculated for all experiments (Fig. 5/a). The best fit of the data by a least squares regression analysis gave the equation y (slope of decline) =

Table 24. Mean total viable aerobic heterotrophic bacterial concentrations in water runoff from seven Rhode River basins

		TVC concentrations (cells x 10^3/ml)			
Basin	Season	Mean	± S.D.	n*	Range
101	winter	421	311	7	60 - 830
	spring	417	989	13	30 - 3500
	summer	25	44	10	20 - 150
	fall	12	12	13	3.7 - 46
	year	204	578	43	2.0 - 3500
102	winter	387	443	7	80 - 1100
	spring	94	159	12	3.7 - 500
	summer	48	52	11	5.3 - 160
	fall	51	91	13	4.1 - 320
	year	117	229	43	3.7 - 1100
103	winter	599	776	7	80 - 2200
	spring	66	123	12	8.3 - 450
	summer	51	97	11	3.0 - 340
	fall	40	75	12	3.5 - 262
	year	143	372	42	3.0 - 2200
105	winter	65	85	6	4.7 - 230
	spring	90	164	10	4.7 - 550
	summer	40	45	10	3.7 - 133
	fall	34	73	13	3.6 - 276
	year	55	100	39	3.6 - 550
106	winter	293	618	5	5.7 - 1400
	spring	96	153	13	5.3 - 520
	summer	126	203	13	7.0 - 580
	fall	22	45	11	2.3 - 157
	year	109	251	42	2.3 - 1400
107	winter	350	475	5	4.3 - 1100
	spring	26	23	11	1.3 - 83
	summer	27	23	11	6.3 - 73
	fall	23	29	11	4.5 - 106
	year	68	193	38	1.3 - 1100
108	winter	370	346	6	9.0 - 820
	spring	31	29	11	6.7 - 110
	summer	32	29	13	6.0 - 110
	fall	25	51	11	2.9 - 180
	year	79	176	41	2.9 - 820
All basins	winter	364	473	43	4.3 - 2200
	spring	123	417	82	1.3 - 3500
	summer	52	49	79	2.0 - 580
	fall	30	59	84	2.3 - 320
	year	112	313	288	1.3 - 3500

*n = Number of samples

Fig. 5. Effect of temperature on the survival of *S. faecalis* MC-5 cells. Correlation between average viable cell numbers and water temperatures throughout a 7-day period of all experiments was estimated by regression calculations. Fig. 5/a. The slope of decline in viable cell numbers affected by each water temperature was estimated and plotted against the temperatures. A linear least-squares regression calculation gave $y = 0.267 + 0.045\ x$ and a positive correlation of $r = 0.892$. Fig. 5/b. t 1/2 at each temperature was estimated and plotted against the temperature. A linear least-squares regression calculation gave $y = 79.8 - 3.74\ x$ and an inversely proportional correlation of $r = 0.569$.

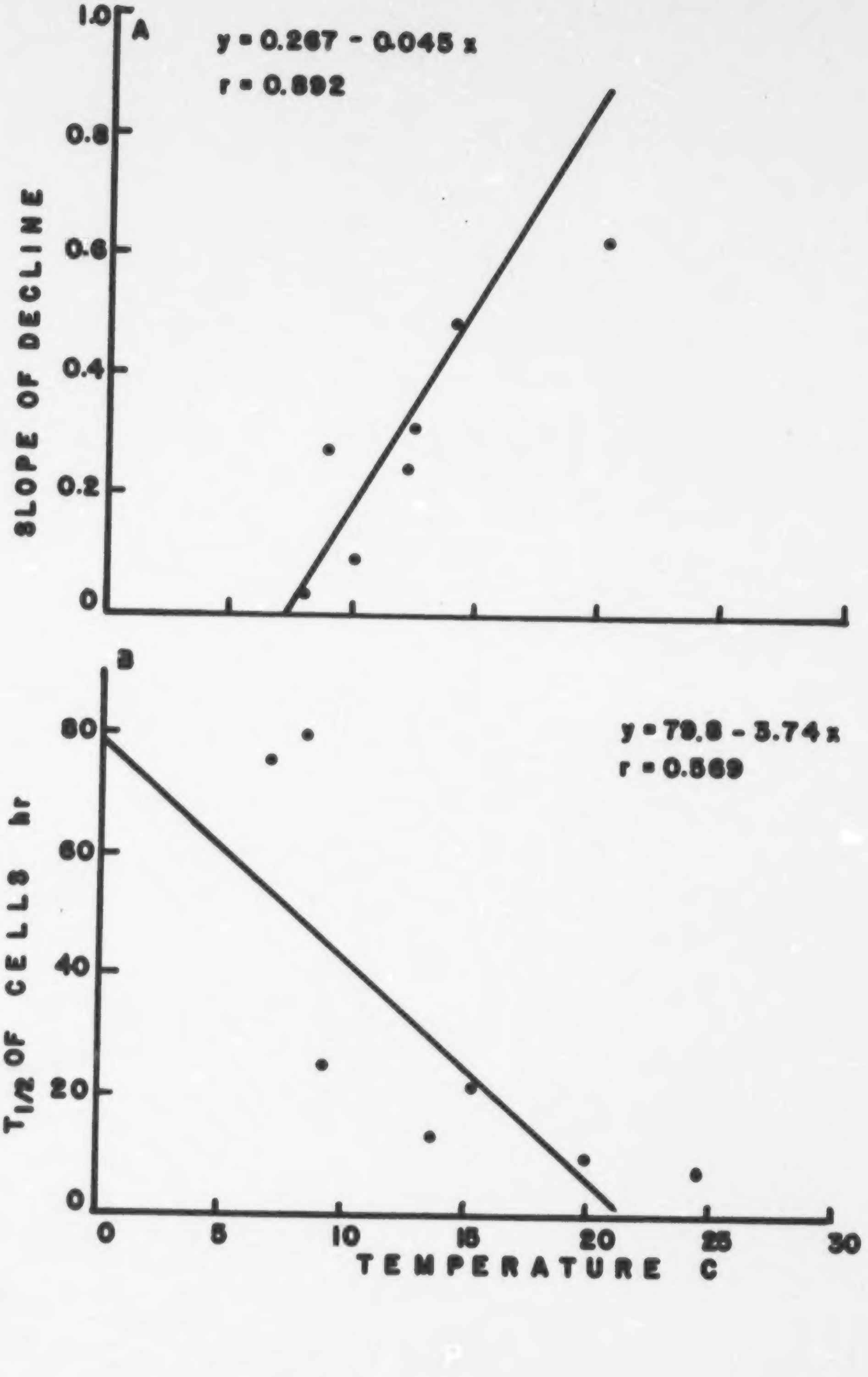

A
y = 0.267 - 0.045 x
r = 0.892
1.0
0.8
0.6
0.4
0.2
0
SLOPE OF DECLINE
B
y = 79.8 - 3.74 x
r = 0.569
80
60
40
20
0
$T_{1/2}$ OF CELLS hr
0
5
10
15
20
25
30
TEMPERATURE C

Table 25: Physical parameters of the water at designated times of the year.[a]

Date of 1976	Temp(c)		Dissolved Oxygen				Salinity (‰)	
			mg/liter		Saturation %			
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
17-23 Feb.	7.2	10.7	10.5	15.0	95	129	5.2	6.2
1-6 March	8.2	11.5	13.0	15.0	113	141	3.0	4.4
9-15 March	7.0	9.1	10.9	13.5	91	120	3.2	3.9
22-28 March	11.0	13.5	10.2	15.0	94	148	3.8	5.0
30 March-6 April	11.5	12.0	11.0	13.2	103	127	4.4	4.9
12-18 April	10.5	20.5	11.0	15.0	101	172	4.4	4.6
20-26 April	16.0	23.0	9.0	11.7	94	142	4.7	6.2

[a] Data were collected by the Geological Survey's water quality monitor located in the Rhode River at the Smithsonian Institution's pier. Data as presented consist of daily maximum and minimum values summarized by week to give weekly averages and extremes.

0.267 + 0.045 x (water temperature). The correlation coefficient was r = 0.892.

Survival of *S. faecalis* MC-5 effected by temperature was also expressed as time (hours) needed for 50% reduction of viable cell population(T 1/2)(Fig. 5/b). An inversely proportional relationship existed between the above two parameters. A least squares regression analysis gave the following equation y (T 1/2) = 79.8 - 3.74 x (temperature). The correlation coefficient was r = 0.569. The survival of *S. faecalis* MC-5 at various temperatures was: at 5 C,T 1/2=60 hr; at 10 C,T 1/2=40 hr; and at 20,C T 1/2=6 hr,respectively. The survival of *S. faecalis* MC-5 at 10 C estuarine water appeared twice as long than in well water, in which T 1/2=22 hr, as reported by McFeters et. al. (23).

The physical parameters of the estuarine environment varied during this study (Table 25). The temperature ranged from 7 to 23 C, the D.O. ranged from 9 to 15 mg/L, and the salinity ranged from 3.0 to 6.2‰. These values are considered representative of the water quality of the estuary during the spring. Although relatively small changes were observed in D.O., temperature and salinity levels in the water, their effects were different on *S. faecalis* MC-5 survival when these parameters were examined individually (Table 26). It appears that *S. faecalis* MC-5 survival is effected most by temperature (r = 0.750),next by salinity (r = 0.537),and least by D.O. (r = 0.425).

The data was also analysed by multiple linear regression analysis to establish linear relations among more than two independent variables, temperature, salinity, and DO (Table 27). Regressions were performed and multiple coefficients of determination (R^2) estimated. It appeared that 56% of the variance in viable cell numbers was explained by water tempera-

Table 26: Results of the two-variable linear regression analysis of S. faecalis MC-5 survival after 3 days in the Rhode River.

Variables			
Dependent	Independent		
Viable cell numbers	Dissolved oxygen	Temperature	Salinity
log cells/ml	mg/l	C	‰
Correlation Coefficient	0.425	0.750	0.537

Table 27: Results of the multiple correlation analysis of four variables of S. faecalis MC-5 survival after 3 days in the Rhode River.

Determination	Steps in regression		
	1	2	3
Variable	Temperature	Temperature + D.O.	Temperature + D.O. + Salinity
Coefficients of determination	0.562	0.562	0.753

ture; the combined effect of temperature and D.O. remained the same ($R^2 = 0.562$); and the addition of all 3 parameters, salinity, temperature and D.O., explained 75% of variation in viable cell numbers. Thus, survival of *S. faecalis* MC-5 was affected in order of decreasing importance by temperature, salinity, and D.O. Montmorillonite and illite had no effects on the survival of *S. faecalis* MC-5 exposed to the estuarine environment.

2. Cell injury and repair: The effect of injury during washing *S. faecalis* MC-5 cells with standard and gelatin phosphate buffers was evaluated (Table 28). It appeared that gelatin buffer washed cells survival was high and few percent of the cell population died during the duration of the experiment, 48 hr *in situ* exposure to the estuarine environment. The survival rate of washed cells with standard buffer was somewhat reduced, with a larger percent of the population dying. Cell injury was about the same with both buffers. Cell injury increased, however, proportionally with *in situ* exposure time.

The survival and injury characteristics of standard PO_4 buffer washed cells of *S. faecalis* MC-5 in membrane filter chambers over 7 days exposure period in estuarine environment was next tested (Table 29). The ability of these cells to survive in the estuarine water was relatively high. Cell injury remained low, ranging from 3 to 19% of the original population after 6 days in the estuary. The above data indicated that injury of *S. faecalis* MC-5 populations was probably a non-lethal type and cell repair could occur.

In order to evaluate that these injured *S. faecalis* MC-5 cells could repair cell injury, cells were exposed to 0 to 48 hr in the estuarine environment and cell suspensions were plated on selective (ADA) and non-selective

Table 28. Effect of standard phosphate and gelatin phosphate buffer solutions upon death and injury to *S. faecalis* MC-5 cells suspension in membrane filter chambers suspended in estuarine water.

Exposure time (hr)	Buffer				% Death Buffer		% Injury Buffer		% Survival Buffer	
	Standard PO_4		Gelatin PO_4		Standard PO_4	Gelatin PO_4	Standard PO_4	Gelatin PO_4	Standard PO_4	Gelatin PO_4
	TSA	ADA	TSA	ADA						
	cells x 10^8/ml									
0	1.0	1.0	1.1	1.1	0	0	0	0	100	100
6	1.2	1.6	1.2	1.3	80	9	33	8	20	91
8	1.8	1.4	1.1	1.4	20	0	22	27	80	100
24	1.5	1.2	1.1	1.5	50	0	20	36	50	100
48	1.2	1.1	1.0	1.8	20	9	8	80	80	91

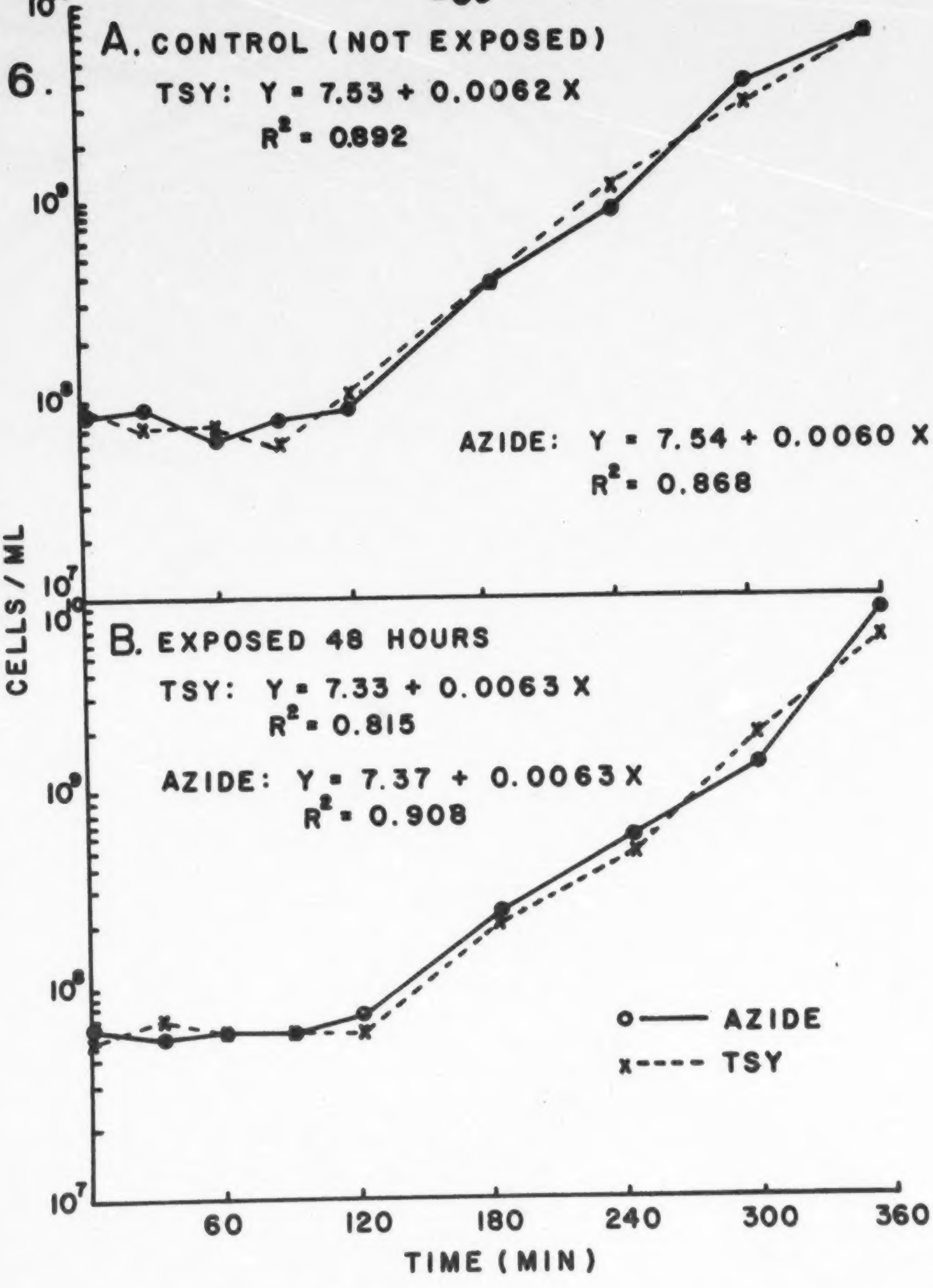
(TSY) media (Fig. 6). High correlations were found between log cell numbers and time of 0 hr exposed cells in the water on both ADA and TSY media. Least squares regression analysis gave the following equations: y (log cells/ml) = 7.53 + 0.006 x (time, hr) and a corelation coefficient of $r = 0.948$ on ADA medium; y (log cells/ml) = 7.54 + 0.006 x (time, hr) and $r = 0.931$ on TSY medium; similarly cells exposed to the estuary for 48 hr the equations were: y (log cells/ml) = 7.33 + 0.006 x (time, hr) and $r = 0.902$ on TSY medium; and y (log cells/ml) = 7.37 + 0.006 x (time, hr) and $r = 0.953$ on ADA medium respectively. The slopes were identical in the above experiments, indicating the same growth rates of *S. faecalis* MC-5 on both selective and non-selective media. Thus, relatively equal detection of viable cells for control (0 hr) and 48 hr exposed *in situ* cell populations indicated that the environmental stress of the estuary appears to be non-lethal type of injury.

Table 29. The survival and injury of standard phosphate washed *S. faecalis* MC-5 cells in membrane filter chambers over 7 days exposure period in the estuarine water.

Exposure Time (days)	Cells x 10^8/ml		% Death	% Survival	% Injury
	ADA	TSA			
0	2.3	2.3	0	100	0
1	1.33	1.27	45	55	5
2	1.70	1.43	38	62	19
3	1.47	1.43	38	62	3
6	1.30	1.53	38	67	15
7	1.23	1.63	29	71	75

Fig. 6. Evaluation of the type of cell injury of S. *faecalis* MC-5 exposed to estuarine environment for 48 hrs.

Fig. 6.


A. CONTROL (NOT EXPOSED)
TSY: Y = 7.53 + 0.0062 X
R² = 0.892
AZIDE: Y = 7.54 + 0.0060 X
R² = 0.868
B. EXPOSED 48 HOURS
TSY: Y = 7.33 + 0.0063 X
R² = 0.815
AZIDE: Y = 7.37 + 0.0063 X
R² = 0.908
o—— AZIDE
x---- TSY
10¹⁰
10⁹
10⁸
10⁷
CELLS / ML
60
120
180
240
300
360
TIME (MIN)

DISCUSSION

It is difficult to rank all the factors contributing to FC discharge from a rural watershed. We have selected a few which appeared the most important. One has to keep in mind that this study was completed in an area where basin size varied between 28 to 254 ha, the stream length varied between 0.7 - 6.7 km, the slopes average 5%, land use was complex and the animal population was 0.53 unit/ha. Therefore, the conclusions may have the limitations imposed by the above factors.

Water flow: Water flow is an important variable affecting in discharging of fecal organisms. This fact has been shown by several workers (12, 14, 27, 29, 36). Our present data indicate that the relationship between FC discharge and water flow may be complicated. FC discharge was little affected when water flow was between 5 to 10,000 l ha-day^{-1}. FC discharge increased exponentially when water discharge increased over the value of 10,000 l/ha-day. This relationship appears to be similar to that reported by other investigators for total viable bacterial discharge (12) and for sediment discharge (6).

There are other factors which may be important in FC discharge. The number of bacteria in or on the soil and vegetation also could influence FC discharge (13). This is especially important when various animal densities and the deposition of bacteria produced by them on the soil and vegetation is considered.

One of the factors influencing bacterial pollution the most is the rate of water flow. This can be estimated by periodical sampling. or by more sophisticated automated integrated sampling. To calculate area yields, the determination of total water discharge is essential. We therefore, determined how closely one can estimate waterflow from spot samples taken weekly from the basins. We compared this estimation with the result of continuous flow measurements. This comparison is important because for microbial analysis one must use spot sampling and the knowledge of water flow is essential in calculating area yields.

The weekly spot sampling method of estimating bacterial discharge has the disadvantage that sampling times are random with respect to rainfall patterns. Samples taken during the peak of a storm event may grossly over estimate the water flow and bacterial discharge for that week, while samples taken at base flow which miss one or more periods of rain may underestimate the true bacterial discharge levels. The bacterial discharge data from the seven basins are considered as minimum values, because samples were taken mostly during base flow conditions. Although, weekly flow values were different depending upon the use of either spot sampling or continuous flow values, the yearly flow estimates by the two methods were in very close agreement leading us to believe that bacterial discharge levels for each basin are relatively close estimatesof pollution.

Seasons: The season of the year is a determining factor in the level of bacterial pollution. This is evident from this study as well as from previous studies (Correll et. al. 1976). The seasonal fecal discharge levels can be different from one year to the next from the same watershed (14, 15). The FC discharge was the highest during spring and summer of 1974-75 water year, whereas it was the highest during spring and winter during the 1973-74 water year. The difference observed between the two years is probably due to the rainfall pattern, since the 1974-75 year was wet and the 1973-74 year had an extremely dry summer. The yearly FS discharge appeared to be at the same magnitude as yearly FC discharge. The FS discharge was the highest in the summer and the lowest in the fall and winter which is similar to FC discharge pattern.

Basin characteristics: Bacterial discharge increased proportionately to basin size and stream length. In our opinion the relationship between basin characteristics and bacterial discharge is only for general use. This relationship merely points to the fact that FC and FS discharge is strongly influenced by the flow of water which in turn is determined by basin characteristics. Therefore, it is not surprising that FC and FS discharge is related to basin characteristics. Estimations such as FC discharge/stream length-year or FC discharge/year varied much more between basins than FC discharge/ha-year and are considered less useful. While discharge expressed on the ha stream length and basin size all had statistically significant relationships with the total FC and FS discharge, the values expressed on the basis of drainage density were not significant.

We have been concerned with the fact that pastures may contribute considerably to FC discharge. We estimated (14, 16) that 1-6% of the FC bacteria produced by domesticated livestock grazing the land are washed from the watersheds through streams that have lengths up to 6.7 km. This further strengthens the importance of the contribution of pastures to the FC discharge from a given watershed.

Land use: A statistical model (8) appears to be useful in estimating the contribution of various land use types to FC and FS discharge. The alternative to this method is to estimate bacterial discharge from a single land use basin. Such basins are difficult to find in a complex land use system, as most stream banks are wooded, while cultivated areas are usually located further from the stream channel. We are in the process of determining the accuracy of the use of a statistical model for FC and FS discharge by determining the contribution of a single land use i.e. cultivated land, to the total bacterial discharge by direct sampling. Until this work is completed we can only use relative comparisons. However, the model estimates that 68% of the total FC discharge and 85% of total FS discharge, were from pasture, which occupied only 22% of the total watershed area. The contribution of cultivated and forested areas to bacterial pollution was much smaller in magnitude, although represented a much larger proportion of the land. We consider our calculations realistic, although we need to compare indicator bacterial discharge values from both kind of basins, those with complex and those with single land use.

Survival: Knowledge on the survival of S. faecalis in estuaries is essential in determining the degree of bacterial dispersal and duration of their presence in the water. This information is needed in assessing the reliability of current water quality monitoring procedures. Understanding the survival characteristics of S. faecalis is a way to determine the seriousness of fecal pollution from rural sources. In this study, we have shown that S. faecalis enter the Rhode River estuary in large numbers and contribute significantly to the fecal pollution of the estuary.

Few studies have examined survival characteristics of S. faecalis within an estuarine system. Existing survival studies were performed in other environments. In soils (37) and in fresh water S. faecalis has been found to persist longer at 10 C than 20 C temperatures (3, 28), survived 3-5 times longer in the subartic than in the temperate zones (22), and exceeded the die-off rate of fecal coliforms (32, 33). The survival of S. faecalis also parallels the survival of enteric viruses better than other indicator organisms. Therefore, it may also be used as an estimate of viral pollution (9). In this work we have overcome some of the shortcomings of previous studies. We chose the estuarine environment to assess concomitantly the effect of physical parameters on S. faecalis MC-5 survival over an extended period of time. We analyzed the collected data statistically in an attempt to evaluate the combined effects of time,water temperature, D.O. and salinity on S. faecalis MC-5 survival. We used the convenience of dialysis chambers (28) that allowed an in situ examination of the survival of S. faecalis MC-5 of fecal origin isolated from the study site.

The survival of S. faecalis MC-5 in the natural environment of the Rhode River is affected by several factors;they are,in order of importance: the time the organisms are exposed to the water; seasonal variation of 5 to 30 C in water temperature; salinity; and D.O. It appeared that survival characteristics are in general similar for both S. faecalis MC-5 and E. coli MC-6 (14) in the estuary. With the exception that die-off rate(T 1/2)of S. faecalis MC-5 effected by temperature was twice as fast, than estimated for E. coli MC-6 (14). Thus, water temperature appears to have distinct but predictable effect on the survival of fecal bacteria, although it is recommended to be examined separately for each fecal bacterial species.

Sedimentation and flocculation may play an important role in the removal of bacteria from the water column and attachment of bacteria to particulates can aid in their preservation. Montmorillonite addition extended the survival of E. coli MC-6 in the Rhode River estuary. In contrast however, this clay had no protection on the survival of S. faecalis MC-5. It is interesting to speculate on the possibility that the prolonged in situ survival of fecal coliform but not fecal streptococci can indicate that fecal coliforms are more serious pollutants in the estuarine environment than those of fecal streptococci.

Cell injury and repair: A large proportion of cell populations exposed to an aquatic environment is injured (4). These injured cells are an integral part of the total viable cell population. In order to accurately evaluate the proportion of damaged cells, one must allow cells to recover before enumeration. Cells must be allowed to repair injury. In the literature, Bissonnette et. al. (4) demonstrated that gelatin phosphate buffer and non-selective media allow cells from a mountain stream to recover more easily. No such relationship was found in this study. Both repair and injury experiments showed that enumeration of cells prepared with standard phosphate buffer and selective media were the same as those of cells prepared with gelatin phosphate buffer and non-selective media. Neither enriched media nor gelatin phosphate buffer had any effect on S. faecalis populations exposed to the estuarine environment. This is probably due to the higher nutrient concentrations present in the near coastal aquatic environment than in the dilute mountain streams (4).

From a practical viewpoint, this study relates to the use of water temperature as an important predictor of fecal streptococcii survival in an estuary.

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LITERATURE CITED

1. Standard Methods for the Examination of Water and Wastewater. (1971) 13th edition. p. 874. American Public Health Association, Inc. New York, N. Y.

2. Recommended Procedures for the Examination of Sea Water and Shellfish. (1970) 4th edition. p. 35. American Public Health Association, Inc. New York, N. Y.

3. Ballantine, R. K. and F. W. Kittrell. (1968) Observations of fecal coliforms in several recent stream pollution studies. p. 80-126. In Proc. of Symp. on "Fecal coliform bacteria in water and wastewater." Bureau of Sanitary Engineering, California State Department of Public Health, Los Angeles, California.

4. Bissonnette, G. K., J. J. Jezeski, G. A. McFeters, and D. G. Stuart. 1975. Influence of environmental stress on enumeration of indicator bacteria from natural water. Applied Microbiology. 29: 186-194.

5. Blair, J. E., E. H. Lennette, and J. P. Truant. 1973. Manual of Clinical Microbiology. Williams and Wilkens Co., Baltimore, Md. p. 151-174.

6. Bormann, F. H., E. Likens, and J. S. Eaton. (1969) Biotic regulation of particulate and solution losses from a forest ecosystem. Bioscience 19: 600-610.

7. Brezenski, F. T. and R. Russomanno. (1969) Detection and use of Salmonellae in studying polluted tidal estuaries. J. Water Pollut. Cont. Fed. 41: 725-737.

8. Chirlin, Gary and D. L. Correll. (1977) A statistical approach to the calculation of area yield coefficients based on land use. In Water-

shed Research in Eastern Watershed Program. Chesapeake Bay Center for Environmental Studies, Smithsonian Institution, Edgewater, Md. Feb. 28 - March 3, 1977. Smithsonian Institution publication.

9. Cohen, J., and H. I. Shuval. 1973. Coliforms, fecal coliforms, and fecal streptococci as indicators of water pollution. Water, Air, and Soil Pollution. 2: 85-95.

10. Correll, D. L. (1977) An Overview of the Rhode River Watershed Program. In Watershed Research in Eastern North America. Chesapeake Bay Center for Environmental Studies, Smithsonian Institution, Edgewater, Md. Feb. 28 - March 3, 1977. Smithsonian Institution publication.

11. __________, J. W. Pierce and M. A. Faust. 1976. A quantitative study of the nutrient, sediment and coliform bacterial constituents of water runoff from the Rhode River watershed. Proceedings of a Southeastern Regional Conference on Non-point Sources of Water Pollution. Virginia Polytechnic Institute and State University, Blacksburg, Virginia; May, 1975. p. 131-143.

12. Evans, M. R. and J. D. Owens. (1973) Soil bacteria in land drainage water. Water Res. 7: 1295-1300.

13. Evans, M. R. and J. D. Owens. (1972) Factors affecting the concentration of fecal bacteria in land drainage water. J. Gen. Microbiol. 71: 477-485.

14. Faust, M. A. (1976/a) Coliform bacteria from diffuse sources as a factor in estuarine pollution. Water Research 10: 619-27.

15. Faust, M. A. (1976/b) Non-point Source Studies on Chesapeake Bay: I. Bacterial Contamination from the Rhode River Watershed, concentrations and survival studies in the estuary. Chesapeake Research Consortium Incorporated Publication No. 53. p. 69.

16. Faust, M. A., A. E. Aotaky, and M. T. Hargadon. (1975) Effect of physical parameters on the in situ survival of Escherichia coli MC-6 in an estuarine environment. Applied Microbiol. 30: 800-806.

17. Gameson, A. L. H., D. Munro, and E. B. Pike. (1970) Effects of certain parameters on bacterial pollution at a coastal site. p. 34-54. Symp. on Water Pollution Control in Coastal Areas. Bouremouth, England.

18. Geldreich, E. E. (1970) Applying bacteriological parameters to recreational water quality. J. Am. Water Works Assoc. 62: 113-120.

19. Geldreich, E. E. (1967) Origins of microbial pollution in streams. In Transmission of viruses by the water route. Berg, G. ed. p. 355. John Wiley and Sons, New York, N. Y.

20. Geldreich, E. E., and B. A. Kenner. 1969. Concepts of fecal streptococci in stream pollution. Water Pollut. Cont. Fed. 41: R336-352.

21. Geldreich, E. E., L. C. Best, B. A. Kenner, and D. J. van Donsel. (1968) The bacteriological aspects of stormwater pollution. J. Water Pollut. Cont. Fed. 40: 1861-1872.

22. Gordon, R. C. 1972. Winter survival of fecal indicator bacteria in a subarctic Alaskan river. EPA-R2-72-013.

23. Hendricks, C. W. (1971) Enteric bacterial metabolism of stream sediment eluates. Can. J. Microbiol. 17: 551-556.

24. Hendricks, C. W. and S. M. Morrison. (1967) Multiplication and growth of selected enteric bacteria in mountain stream water. Water Res. 1: 567-576.

25. Ketchum, B. H., J. C. Ayres, and R. F. Vaccaro. (1952) Process contributing to the decrease of coliform bacteria in tidal estuary. Ecology 33: 247-258.

26. Kirchner, W. B. (1975) An examination of the relationship between drainage basin morphology and the export of phosphorus. Limnol. Oceanog. 20: 267-70.

27. Kunkle, S. H. (1970) Concentrations and cycles of bacterial indicators in farm surface runoff. p. 49-60. In Relationship of Agriculture to Soil and Water Pollution. Presented at the conference on Agricultural Waste Management. Cornell University, Ithaca, N. Y.

28. McFeters, G. A., and D. G. Stuart. (1972) Survival of coliform bacteria in natural waters: field and laboratory studies with membrane-filter chambers. Appl. Microbiol. 24: 805-811.

29. Morrison, S. M. and J. F. Fair. (1966) Influence of environment on stream microbial dynamics. p. 21. Colorado State University Hydrology Papers No. 13. Fort Collins, Colorado.

30. Ongley, E. D. 1973. Sediment discharge from Canadian basins into Lake Ontario. Can. J. Earth Sciences 10: 146-56.

31. Rheinheimer, G. (1968) Results and problems of microbiological estuarine investigation. Mitt. Int. Verein. Theor. Angew Limnol. 14: 155-63.

32. Smith, R. J., R. M. Twedt, and L. K. Flanigan. (1973) Relationship of indicator and pathogenic bacteria in stream water. J. Water Pollut. Cont. Fed. 45: 1737-1745.

33. Smith, R. J., and R. M. Twedt. (1971) Natural relationship of indicator and pathogenic bacteria in stream waters. J. Water Pollut. Cont. Fed. 43: 2200-2209.

34. Strobel, G. A. (1968) Coliform - fecal coliform bacteria in tidal waters. J. Sanit. Eng. Div. Am. Soc. Civil Eng. 94: 641-656.

35. Weibel, S. R., R. J. Anderson and R. L. Woodware. (1964) Urban runoff as a factor in stream pollution. J. Water Pollut. Cont. Fed. 36: 914-924.

36. Weidner, R. B., A. G. Christenson, S. R. Weibel and G. G. Roebeck. (1969) Rural runoff as a factor in stream pollution. J. Water Pollut. Cont. Fed. 41: 377-384.

37. Van Donsel, D. J., E. E. Geldreich and N. A. Clarke. (1967) Seasonal variations in survival of indicator bacteria in soil and their contribution to storm water pollution. Appl. Microbiol. 15: 1362-1370.

APPENDIX

Table 1: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 101.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/day/ha	$FCx10^6$ discharged/day	$FCx10^6$ discharged/day/ha	$FCx10^6$ discharged/day/animal
006	0.52	2.17	5,720.0	23.89	17.55
013	3.34	13.95	367.4	1.53	1.13
027	1.97	8.23	492.5	2.06	1.51
034	1.44	6.02	6,624.0	27.67	20.32
041	1.78	7.44	765.4	3.20	2.35
049	1.88	7.85	4,512.0	18.85	13.84
055	2.38	9.94	666.4	2.78	2.04
062	1.29	5.39	554.7	2.32	1.70
069	1.14	4.76	5,244.0	21.90	16.09
076	6.65	27.78	159,600.0	666.67	489.57
083	5.33	22.26	127,920.0	534.34	329.39
090	4.19	17.50	963.7	4.03	2.96
097	2.06	8.60	9,476.0	39.58	29.07
104	1.61	6.73	692.3	2.89	2.12
111	1.61	6.73	627.9	2.62	1.93
118	2.27	9.48	10,442.0	43.62	32.03
125	4.35	18.17	47,850.0	199.87	146.78
132	1.97	8.23	295.5	1.23	0.91
139	1.97	8.23	78.8	0.33	0.24
147	1.29	5.39	296.7	1.24	0.91
153	1.61	6.73	112.7	0.47	0.35
160	0.57	2.38	1,140.0	4.76	3.50
167	0.48	2.01	11,520.0	48.12	35.34
174	0.30	1.25	7,200.0	30.08	22.09
181	0.27	1.13	6,480.0	27.07	19.88
188	0.17	0.71	1,870.0	7.81	5.74
195	26.82	112.03	643,680.0	2,688.72	1,974.48
202	5.69	23.77	136,560.0	570.43	418.90
209	0.61	2.55	1,830.0	7.64	5.61
216	0.27	1.13	810.0	3.38	2.48
223	0.44	1.84	1,100.0	4.59	3.37
230	1.97	8.23	6,895.0	28.80	21.15
237	0.44	1.84	528.0	2.21	1.62
244	3.61	15.08	34,656.0	144.76	106.31
251	1.07	4.47	2,033.0	8.49	6.24
258	0.37	1.55	666.0	2.78	2.04
265	0.57	2.38	1,425.0	5.95	4.37
272	3.47	14.49	4,164.0	17.39	12.77
280	1.60	6.68	640.0	2.67	1.96
287	2.27	9.48	5,675.0	23.71	17.41
293	3.08	12.87	3,696.0	15.44	11.34
301	2.17	9.06	325.5	1.36	1.00
307	1.60	6.68	160.0	0.67	0.49
314	1.69	7.06	7,436.0	31.06	22.81
321	2.07	8.65	-	-	-
328	1.60	6.68	800.0	3.34	2.45
335	2.07	8.65	1,242.0	5.19	3.81
342	1.44	6.02	1,368.0	5.71	4.20
349	1.52	6.35	608.0	2.54	1.87
356	1.14	4.76	114.0	0.48	0.35
363	1.87	7.81	56.1	0.23	0.17

Table 2: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 102.

Day of 1975	Flow $L\times10^6$/day	Flow $L\times10^3$/day/ha	$FC\times10^6$ discharged/day	$FC\times10^6$ discharged/day/ha	$FC\times10^6$ discharged/day/animal
006	0.44	2.44	189.2	1.05	4.85
013	2.71	15.05	12,466.0	69.22	319.64
027	1.78	9.88	4,272.0	23.72	109.54
034	1.21	6.72	2,904.0	16.12	74.46
041	1.78	9.88	8,188.0	45.46	209.95
049	1.69	9.38	659.1	3.66	16.90
055	2.17	12.05	2,018.1	11.21	51.75
062	1.07	5.94	160.5	0.89	4.12
069	0.09	0.50	38.7	0.21	0.99
076	6.64	36.87	15,936.0	88.48	408.62
083	5.69	31.59	136,560.0	758.25	3,501.54
090	2.38	13.21	2,213.4	12.29	56.75
097	1.52	8.44	653.6	3.63	16.76
104	1.14	6.33	5,244.0	29.12	134.46
111	1.14	6.33	5,244.0	29.12	134.46
118	1.97	10.94	9,062.0	50.32	232.36
125	3.90	21.65	9,360.0	51.97	240.00
132	1.69	9.38	152.1	0.84	3.90
139	1.78	9.88	53.4	0.30	1.37
147	0.88	4.89	26.4	0.15	0.68
153	0.88	4.89	26.4	0.15	0.68
160	0.33	1.83	7,920.0	43.98	203.08
167	0.27	1.50	6,480.0	35.98	166.15
174	0.15	0.83	1,650.0	9.16	42.31
181	0.15	0.83	3,600.0	19.99	92.31
188	0	0	-	-	-
195	10.59	58.80	254,160.0	1,411.22	6,516.92
202	6.26	34.76	150,240.0	834.20	3,852.31
209	0.44	2.44	440.0	2.44	11.28
216	0.21	1.17	315.0	1.75	8.08
223	0.19	1.05	760.0	4.22	19.49
230	1.21	6.72	3,872.0	21.50	99.28
237	0.24	1.33	456.0	2.53	11.69
244	2.83	15.71	62,260.0	345.70	1,596.41
251	0.71	3.94	1,846.0	10.25	47.33
258	0.27	1.50	864.0	4.80	22.15
265	0.40	2.22	1,120.0	6.22	28.72
272	2.71	15.05	5,691.0	31.60	145.92
280	1.07	5.94	535.0	2.97	13.72
287	1.44	8.00	2,016.0	11.19	51.69
293	2.27	12.60	4,994.0	27.73	128.05
301	2.17	12.05	2,604.0	14.46	66.77
307	1.14	6.33	627.0	3.48	16.08
314	1.21	6.72	3,751.0	20.83	96.18
321	1.69	9.38	4,394.0	24.40	112.67
328	1.63	9.05	1,059.5	5.88	27.17
335	1.60	8.88	4,640.0	25.76	118.97
342	1.14	6.33	171.0	0.95	4.38
349	1.14	6.33	228.0	1.27	5.85
356	0.82	4.55	1,558.0	8.65	39.95
363	1.52	8.44	608.0	3.38	15.59

Table 3: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 103.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/ day/ha	$FCx10^6$ discharged/ day	$FCx10^6$ discharged/ day/ha	$FCx10^6$ discharged/ day/animal
006	0.37	1.45	777.0	3.05	9.25
013	3.47	13.64	-	-	-
027	1.52	5.97	653.6	2.57	7.77
034	1.14	4.48	490.2	1.93	5.84
041	1.87	7.35	804.1	3.16	9.57
049	1.87	7.35	8,602.0	33.81	102.40
055	2.27	8.92	976.1	3.84	11.62
062	1.21	4.76	1,125.3	4.42	13.40
069	1.07	4.21	460.1	1.81	5.48
076	6.45	25.35	15,480.0	60.85	184.29
083	6.85	26.93	164,400.0	646.23	1,957.14
090	3.08	12.11	708.4	2.78	8.43
097	2.38	9.36	1,023.4	4.02	12.18
104	1.78	7.00	694.2	2.73	8.26
111	1.69	6.64	388.7	1.53	4.63
118	2.83	11.12	650.9	2.56	7.75
125	4.66	18.32	11,184.0	43.96	133.14
132	2.49	9.79	224.1	0.88	2.67
139	2.27	8.92	90.8	0.36	1.08
147	1.36	5.35	40.8	0.16	0.49
153	1.36	5.35	54.4	0.21	0.65
160	0.57	2.24	2,622.0	10.31	31.21
167	5.69	22.37	136,560.0	536.79	1,625.71
174	0.24	0.94	1,104.0	4.34	13.14
181	0.24	0.94	5,760.0	22.64	68.57
188	0	0	-	-	-
195	17.06	67.06	409,440.0	1,609.43	4,874.29
202	3.34	13.13	80,160.0	315.09	954.29
209	0.57	2.24	741.0	2.91	8.82
216	0.15	0.58	150.0	0.59	1.79
223	0.18	0.70	270.0	1.06	3.21
230	1.97	7.74	2,561.0	10.07	30.49
237	-	-	-	-	-
244	2.17	8.53	54,250.0	213.25	645.83
251	0.61	2.40	793.0	3.12	9.44
258	0.11	0.43	308.0	1.21	3.67
265	0.40	1.57	400.0	1.57	4.76
272	4.04	15.88	7,676.0	30.17	91.38
280	1.44	5.66	1,224.0	4.81	14.57
287	2.07	8.14	1,035.0	4.07	12.32
293	2.83	11.12	3,962.0	15.57	47.17
301	1.78	7.00	801.0	3.15	9.54
307	1.69	6.64	338.0	1.33	4.02
314	2.49	9.79	2,739.0	10.77	32.61
322	2.17	8.53	1,519.0	5.97	18.08
328	1.87	7.35	467.5	1.84	5.57
335	2.17	8.53	2,061.5	8.10	24.54
342	1.78	7.00	2,314.0	9.10	27.55
349	1.78	7.00	356.0	1.40	4.24
356	1.36	5.35	1,496.0	5.88	17.81
363	2.07	8.14	310.5	1.22	3.70

Table 4: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 105.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/day/ha	FCx10^6 discharged/day	FCx10^6 discharged/day/ha	FCx10^6 discharged/day/animal
006	0.06	1.60	276.0	7.37	8.90
013	1.87	49.96	3,927.0	104.92	126.68
027	0.33	8.82	49.5	1.32	1.60
034	0.21	5.61	315.0	8.42	10.16
041	0.30	8.01	279.0	7.45	9.00
049	0.33	8.82	792.0	21.16	25.55
055	0.37	9.89	159.1	4.25	5.13
062	0.19	5.08	81.7	2.18	2.64
069	0.27	7.21	648.0	17.31	20.90
076	1.28	34.20	5,888.0	157.31	189.94
083	1.61	43.01	3,864.0	103.23	124.65
090	0.48	12.82	1,152.0	30.78	37.16
097	0.30	8.01	69.0	1.84	2.23
104	0.21	5.61	5,040.0	134.65	162.58
111	0.21	5.61	90.3	2.41	2.91
118	0.37	9.89	159.1	4.25	5.13
125	0.77	20.57	1,848.0	49.37	59.61
132	0.33	8.82	306.9	8.20	9.90
139	0.33	8.82	13.2	0.35	0.43
147	0.19	5.08	17.1	0.46	0.55
153	0.19	5.08	5.7	0.15	0.18
160	0.05	1.34	100.0	2.67	3.23
167	0.03	0.80	720.0	19.24	23.23
174	0.002	0.05	48.0	1.28	1.55
181	0.003	0.08	72.0	1.92	2.32
188	0.002	0.05	9.2	0.25	0.30
195	5.51	147.21	132,240.0	3,532.99	4,265.81
202	0.82	21.91	19,680.0	525.78	634.84
209	0.08	2.14	344.0	9.19	11.10
216	0.06	1.60	60.0	1.60	1.94
223	0.03	0.80	150.0	4.01	4.84
230	0.13	3.47	507.0	13.55	16.35
237	0.03	0.80	204.0	5.45	6.58
244	0.57	15.23	3,078.0	82.23	99.29
251	0.09	2.40	198.0	5.29	6.39
258	0.05	1.34	125.0	3.34	4.03
265	0.04	1.07	112.0	2.99	3.61
272	0.61	16.30	1,952.0	52.15	62.97
280	0.21	5.61	126.0	3.37	4.06
287	0.30	8.01	660.0	17.63	21.29
293	0.52	13.89	572.0	15.28	18.45
301	0.27	7.21	324.0	8.66	10.45
307	0.21	5.61	2,100.0	56.10	67.74
314	0.27	7.21	2,133.0	59.99	68.81
321	0.30	8.01	105.0	2.81	3.39
328	0.21	5.61	115.5	3.09	3.73
335	0.30	8.01	390.0	10.42	12.58
342	0.17	4.54	144.5	3.86	4.66
349	0.17	4.54	34.0	0.91	1.10
356	0.11	2.94	5.5	0.15	0.18
363	0.30	8.01	330.0	8.82	10.65

Table 5: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 106.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/day/ha	$FCx10^6$ discharged/day	$FCx10^6$ discharged/day/ha	$FCx10^6$ discharged/day/animal
006	0.11	1.24	264.0	2.98	17.60
013	3.75	42.28	90,000.0	1,014.66	6,000.00
027	0.77	8.68	1,848.0	20.83	123.20
034	0.52	5.86	1,248.0	14.07	83.20
041	0.71	8.00	7,810.0	88.05	520.67
049	0.66	7.44	1,386.0	15.63	92.40
055	0.82	9.24	3,772.0	42.53	251.47
062	0.44	4.98	2,024.0	22.82	134.93
069	0.37	4.17	888.0	10.01	59.20
076	2.49	28.07	59,760.0	673.73	3,984.00
083	2.83	31.91	67,920.0	765.73	4,528.00
090	1.07	12.07	802.5	9.05	53.50
097	0.71	8.00	1,491.0	16.81	99.40
104	0.66	7.44	990.0	11.16	66.00
111	0.71	8.00	305.3	3.44	20.35
118	0.30	3.38	1,380.0	15.56	92.00
125	1.69	19.05	7,774.0	87.64	518.27
132	3.08	34.72	6,468.0	72.92	431.20
139	3.08	34.72	4,620.0	52.09	308.00
147	0.94	10.60	874.2	9.86	58.28
153	0.88	9.92	26.4	0.30	1.76
160	0.15	1.69	3,600.0	40.59	240.00
167	0.40	4.51	9,600.0	108.23	640.00
174	0.27	3.04	567.0	6.39	37.80
181	0.27	3.04	6,480.0	73.06	432.00
188	0.13	1.47	3,120.0	35.17	208.00
195	10.86	122.44	260,640.0	2,938.44	17,376.00
202	1.60	18.04	38,400.0	432.92	2,560.00
209	0.19	2.14	703.0	7.93	46.87
216	0.09	1.01	315.0	3.55	21.00
223	0.09	1.01	360.0	4.06	24.00
230	0.37	4.17	851.0	9.59	56.73
237	0.06	0.68	90.0	1.01	6.00
244	1.07	12.06	12,840.0	144.76	856.00
251	0.24	2.71	576.0	6.49	38.40
258	0.05	0.56	70.0	0.79	4.67
265	0.15	1.69	915.0	10.32	61.00
272	1.28	14.43	4,096.0	46.18	273.07
280	0.57	6.43	2,166.0	24.42	144.40
287	0.71	8.00	3,195.0	36.02	213.00
293	1.21	13.64	8,228.0	92.76	548.53
301	0.71	8.00	1,136.0	12.81	75.73
307	0.61	6.88	1,220.0	13.75	81.33
314	0.71	8.00	4,686.0	52.83	312.40
321	0.77	8.68	1,232.0	13.89	82.13
328	0.52	5.86	1,092.0	12.31	72.80
335	0.77	8.68	2,156.0	24.31	143.73
342	0.52	5.86	832.0	9.38	55.47
349	0.52	5.86	156.0	1.76	10.40
356	0.37	4.17	666.0	7.51	44.40
363	0.66	7.44	547.8	6.18	36.52

Table 6: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 107.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/day/ha	$FCx10^6$ discharged/day	$FCx10^6$ discharged/day/ha	$FCx10^6$ discharged/day/animal
006	0.04	1.36	1.6	0.05	0.05
013	0.84	28.57	-	-	-
027	0.19	6.46	17.1	0.58	0.57
034	0.12	4.08	10.8	0.37	0.36
041	0.19	6.46	7.6	0.26	0.25
049	0.17	5.78	5.1	0.17	0.17
055	0.23	7.82	9.2	0.31	0.31
062	0.14	4.76	21.0	0.71	0.70
069	0.11	3.74	25.3	0.86	0.84
076	0.98	33.33	735.0	25.00	24.50
083	0.54	18.37	12,960.0	440.82	432.00
090	0.25	8.50	57.5	1.96	1.92
097	0.30	10.20	60.0	2.04	2.00
104	0.14	4.76	60.2	2.05	2.01
111	0.14	4.76	12.6	0.43	0.42
118	0.17	5.78	15.3	0.52	0.51
125	0.28	9.52	1,288.0	43.81	42.93
132	0.12	4.08	4.8	0.16	0.16
139	0.19	6.46	5.7	0.19	0.19
147	0.12	4.08	16.8	0.57	0.56
153	0.12	4.08	3.6	0.12	0.12
160	0.08	2.72	1,920.0	65.31	64.00
167	0.05	1.70	1,200.0	40.82	40.00
174	0.045	1.53	207.0	7.04	6.90
181	0.04	1.36	184.0	6.26	6.13
188	0.01	0.34	240.0	8.16	8.00
195	1.78	60.54	42,720.0	1,453.06	1,424.00
202	0.66	22.45	15,840.0	538.78	528.00
209	0.07	2.38	91.0	3.10	3.03
216	0.045	1.53	67.5	2.30	2.25
223	0.045	1.53	22.5	0.77	0.75
230	0.06	2.04	660.0	22.45	22.00
237	0.07	2.38	31.5	1.07	1.05
244	0.11	3.74	1,320.0	44.93	44.00
251	0.05	1.70	165.0	5.62	5.50
258	0.02	0.68	22.0	0.75	0.73
265	0.045	1.53	274.5	9.34	9.15
272	-	-	-	-	-
280	-	-	-	-	-
287	-	-	-	-	-
293	-	-	-	-	-
301	-	-	-	-	-
307	-	-	-	-	-
314	-	-	-	-	-
321	-	-	-	-	-
328	-	-	-	-	-
335	-	-	-	-	-
342	-	-	-	-	-
349	-	-	-	-	-
356	-	-	-	-	-
363	-	-	-	-	-

Table 7: Fecal coliform bacteria in surface water samples affected by water runoff and livestock density at watershed 108.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/day/ha	FCx10^6 discharged/day	FCx10^6 discharged/day/ha	FCx10^6 discharged/day/animal
006	0.30	2.04	69.0	0.47	0.90
013	4.04	27.52	9,696.0	66.05	125.92
027	1.07	7.29	214.0	1.46	2.78
034	0.88	5.99	202.4	1.38	2.63
041	1.07	7.29	246.1	1.68	3.20
049	1.21	8.24	1,815.0	12.36	23.57
055	1.29	8.79	2,709.0	18.45	35.18
062	0.82	5.59	1,968.0	13.41	25.56
069	0.71	4.84	17,040.0	116.08	221.30
076	3.47	23.64	38,170.0	260.01	495.71
083	3.47	23.64	8,328.0	56.73	108.16
090	1.78	12.13	409.4	2.79	5.32
097	1.37	9.33	315.1	2.15	4.09
104	1.22	8.31	48.8	0.33	0.63
111	0.52	3.54	780.0	5.31	10.13
118	1.44	9.81	1,339.2	9.12	17.39
125	2.71	18.46	1,165.3	7.94	15.13
132	1.44	9.81	43.2	0.29	0.56
139	1.36	9.26	54.4	0.37	0.71
147	0.94	6.40	28.2	0.19	0.37
153	1.00	6.81	40.0	0.27	0.52
160	0.52	3.54	5,720.0	38.96	74.29
167	0.48	3.27	1,152.0	7.85	14.96
174	0.21	1.43	2,310.0	15.74	30.00
181	0.21	1.43	5,040.0	34.33	65.45
188	0.08	0.54	22.4	0.15	0.29
195	10.59	72.14	254,160.0	1,731.34	3,300.78
202	2.71	18.46	65,040.0	443.05	844.68
209	0.61	4.16	2,623.0	17.87	34.06
216	0.21	1.43	735.0	5.01	9.55
223	0.21	1.43	105.0	0.72	1.36
230	0.52	3.54	494.0	3.37	6.42
237	0.19	1.29	209.0	1.42	2.71
244	1.78	12.13	8,900.0	60.63	115.58
251	0.61	4.16	915.0	6.23	11.88
258	0.09	0.61	63.0	0.43	0.82
265	0.27	1.84	756.0	5.15	9.82
272	2.71	18.46	4,878.0	33.23	63.35
280	1.21	8.24	1,391.5	9.48	18.07
287	1.60	10.90	1,360.0	9.26	17.66
293	1.87	12.74	3,366.0	22.93	43.71
301	1.28	8.72	3,328.0	22.67	43.22
307	1.28	8.72	704.0	4.80	9.14
314	1.36	9.26	2,992.0	20.38	38.86
321	1.44	9.81	288.0	1.96	3.74
328	1.28	8.72	230.4	1.57	2.99
335	1.60	10.90	1,040.0	7.08	13.51
342	1.21	8.24	181.5	1.24	2.36
349	1.07	7.29	1,016.5	6.92	13.20
356	0.88	5.99	44.0	0.30	0.57
363	1.21	8.24	121.0	0.82	1.57

Table 8: Fecal coliform discharge per unit area from seven Rhode River basins of water year 1974-75.

				Basins			
Months	101	102	103	105	106	107	108
1974-75				FC x 10^8 discharge/ha - month			
December	10.93	79.42	11.13	-*	-*	13.51	36.54
January	4.08	7.23	0.53	8.54	73.67	0.063	4.84
February	2.01	4.02	3.20	2.45	11.83	0.05	3.20
March	91.02	56.47	49.81	21.60	102.09	32.73	30.48
April	6.57	10.78	3.82	13.45	9.41	3.27	1.73
May	0.24	0.09	0.10	0.64	9.46	0.07	0.07
June	8.16	7.16	40.17	1.75	15.98	8.36	6.77
July	243.19	147.83	134.96	284.88	239.26	140.37	153.79
August	13.78	24.57	15.70	7.36	11.16	4.84	4.62
September	2.56	3.47	2.52	4.46	4.45	1.09	3.15
October	3.20	3.70	1.91	7.07	12.58	-*	4.48
November	2.60	3.58	2.23	4.61	5.53	-*	2.01
Annual	388.34	348.32	265.27	356.81	495.42	204.35	249.95

* = weir inoperable

Table 9: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 101.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/ day/ha	FSx10^6 discharged/ day	FSx10^6 discharged/ day/ha	FSx10^6 discharged/ day/animal
006	0.52	2.17	-*	-	-
013	3.34	13.95	-	-	-
027	1.97	8.23	-	-	-
034	1.44	6.02	216.0	0.90	0.66
041	1.78	7.44	4,272.0	17.84	13.10
049	1.88	7.85	4,512.0	18.85	13.84
055	2.38	9.94	57,120.0	238.60	175.21
062	1.29	5.39	1,935.0	8.08	5.94
069	1.14	4.76	2,736.0	11.43	8.39
076	6.65	27.78	73,150.0	305.56	224.39
083	5.33	22.26	127,920.0	534.34	392.39
090	4.19	17.50	879.9	3.68	2.70
097	2.06	8.60	4,944.0	20.65	15.17
104	1.61	6.73	144.9	0.61	0.44
111	1.61	6.73	450.8	1.88	1.38
118	2.27	9.48	5,448.0	22.76	16.71
125	4.35	18.17	870.0	3.63	2.67
132	1.97	8.23	1,832.1	7.65	5.62
139	1.97	8.23	1,832.1	7.65	5.62
146	1.29	5.39	30,960.0	129.32	94.97
153	1.61	6.73	7,406.0	30.94	22.72
160	0.57	2.38	13,680.0	57.14	41.96
167	0.48	2.01	11,520.0	48.12	35.34
174	0.30	1.25	7,200.0	30.08	22.09
181	0.27	1.13	6,480.0	27.07	19.88
188	0.17	0.71	4,080.0	17.04	12.52
195	26.82	112.03	643,680.0	2,688.72	1,974.48
202	5.69	23.77	136,560.0	570.43	418.90
209	0.61	2.55	6,710.0	28.03	20.58
216	0.27	1.13	7,560.0	31.58	23.19
223	0.44	1.84	7,480.0	31.24	22.94
230	1.97	8.23	25,610.0	106.98	78.56
237	0.44	1.84	8,360.0	34.92	25.64
244	3.61	15.08	129,960.0	542.86	398.65
251	1.07	4.47	8,025.0	33.52	24.62
258	0.37	1.55	2,886.0	12.06	8.85
265	0.57	2.38	5,529.0	23.10	16.96
272	3.47	14.49	14,574.0	60.88	44.71
280	1.60	6.68	8,160.0	34.09	25.03
287	2.27	9.48	8,853.0	36.98	27.16
293	3.08	12.87	5,852.0	24.44	17.95
301	2.17	9.06	3,472.0	14.50	10.65
307	1.60	6.68	1,920.0	8.02	5.89
314	1.69	7.06	6,760.0	28.24	20.74
321	2.07	8.65	3,829.5	16.00	11.75
328	1.60	6.68	800.0	3.34	2.45
335	2.07	8.65	3,933.0	16.43	12.06
342	1.44	6.02	2,016.0	8.42	6.18
349	1.52	6.35	6,232.0	26.03	19.12
356	1.14	4.76	1,254.0	5.24	3.85
363	1.87	7.81	748.0	3.12	2.29

* not calculated

Table 10: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 102.

Day of 1975	Flow Lx10^3/day	Flow Lx10^3/ day/ha	FSx10^6 discharged/ day	FSx10^6 discharged/ day/ha	Fsx10^6 discharged/ day/animal
006	0.44	2.44	-*	-	-
013	2.71	15.05	-	-	-
027	1.78	9.88	-	-	-
034	1.21	6.72	907.5	5.04	23.27
041	1.78	9.88	19,580.0	108.72	502.05
049	1.69	9.38	388.7	2.16	9.97
055	2.17	12.05	5,208.0	28.92	133.54
062	1.07	5.94	32.1	0.18	0.82
069	0.09	0.50	8.1	0.04	0.21
076	6.64	36.87	13,944.0	77.42	357.54
083	5.69	31.59	62,590.0	347.53	1,604.87
090	2.38	13.21	71.4	0.40	1.83
097	1.52	8.44	653.6	3.63	16.76
104	1.14	6.33	45.6	0.25	1.17
111	1.14	6.33	79.8	0.44	2.05
118	1.97	10.94	453.1	2.52	11.62
125	3.90	21.65	3,627.0	20.14	93.00
132	1.69	9.38	338.0	1.88	8.67
139	1.78	9.88	1,655.4	9.19	42.45
147	0.88	4.89	4,048.0	22.48	103.79
153	0.88	4.89	9,680.0	53.75	248.21
160	0.33	1.83	7,920.0	43.98	203.08
167	0.27	1.50	6,480.0	35.98	166.15
174	0.15	0.83	3,600.0	19.99	92.31
181	0.15	0.83	1,650.0	9.16	42.31
188	0	0	-	-	-
195	10.59	58.80	254,160.0	1,411.22	6,516.92
202	6.26	34.76	150,240.0	834.20	3,852.31
209	0.44	2.44	4,840.0	26.87	124.10
216	0.21	1.17	8,610.0	47.81	220.77
223	0.19	1.05	4,370.0	24.26	112.05
230	1.21	6.72	22,990.0	127.65	589.49
237	0.24	1.33	8,160.0	45.31	209.23
244	2.83	15.71	186,780.0	1,037.09	4,789.23
251	0.71	3.94	4,970.0	27.60	127.44
258	0.27	1.50	2,268.0	12.59	58.15
265	0.40	2.22	2,360.0	13.10	60.51
272	2.71	15.05	27,100.0	150.47	694.87
280	1.07	5.94	5,457.0	30.30	139.92
287	1.44	8.00	9,360.0	51.97	240.00
293	2.27	12.60	9,080.0	50.42	232.82
301	2.17	12.05	8,897.0	49.40	228.13
307	1.14	6.33	2,964.0	16.46	76.00
314	1.21	6.72	14,520.0	80.62	372.31
321	1.69	9.38	4,394.0	24.40	112.67
328	1.63	9.05	1,141.0	6.34	29.26
335	1.60	8.88	5,920.0	32.87	151.79
342	1.14	6.33	1,083.0	6.01	27.77
349	1.14	6.33	1,026.0	5.70	26.31
356	0.82	4.55	1,886.0	10.47	48.36
363	1.52	8.44	1,185.6	6.58	30.40

* = not calculated

Table 11: Fecal streptococcus in surface water samples affected by water runoff and livestock density in watershed 103.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/day/ha	$FSx10^6$ discharged/day	$FSx10^6$ discharged/day/ha	$FSx10^6$ discharged/day/animal
006	0.37	1.45	-*	-	-
013	3.47	13.64	-	-	-
027	1.52	5.97	-	-	-
034	1.14	4.48	262.2	1.03	3.12
041	1.87	7.35	1,739.1	6.84	20.70
049	1.87	7.35	8,602.0	33.81	102.40
055	2.27	8.92	3,405.0	13.38	40.54
062	1.21	4.76	48.4	0.19	0.58
069	1.07	4.21	160.5	0.63	1.91
076	6.45	25.35	5,998.5	23.58	71.41
083	6.85	26.93	31,510.0	123.86	375.12
090	3.08	12.11	123.2	0.48	1.47
097	2.38	9.36	547.4	2.15	6.52
104	1.78	7.00	71.2	0.28	0.85
111	1.69	6.64	152.1	0.60	1.81
118	2.83	11.12	424.5	1.67	5.05
125	4.66	18.32	1,071.8	4.21	12.76
132	2.49	9.79	224.1	0.88	2.67
139	2.27	8.92	2,111.1	8.30	25.13
147	1.36	5.35	2,040.0	8.02	24.29
153	1.36	5.35	6,256.0	24.59	74.48
160	0.57	2.24	13,680.0	53.77	162.86
167	5.69	22.37	136,560.0	536.79	1,625.71
174	0.24	0.94	2,640.0	10.38	31.43
181	0.24	0.94	576.0	2.26	6.86
188	0	0	-	-	-
195	17.06	67.06	409,440.0	1,609.43	4,874.29
202	3.34	13.13	80,160.0	315.09	954.29
209	0.57	2.24	4,560.0	17.92	54.29
216	0.15	0.58	3,150.0	12.38	37.50
223	0.18	0.70	1,620.0	6.37	19.29
230	1.97	7.74	12,805.0	50.33	152.44
237	-	-	-	-	-
244	2.17	8.53	130,200.0	511.79	1,550.00
251	0.61	2.40	4,880.0	19.18	58.10
258	0.11	0.43	539.0	2.12	6.42
265	0.40	1.57	2,640.0	10.38	31.43
272	4.04	15.88	14,544.0	57.17	173.14
280	1.44	5.66	3,888.0	15.28	46.29
287	2.07	8.14	6,831.0	26.85	81.32
293	2.83	11.12	5,660.0	22.25	67.38
301	1.78	7.00	3,738.0	14.69	44.50
307	1.69	6.64	1,183.0	4.65	14.08
314	2.49	9.79	19,671.0	77.32	234.18
321	2.17	8.53	1,953.0	7.68	23.25
328	1.87	7.35	2,618.0	10.29	31.17
335	2.17	8.53	4,557.0	17.91	54.25
342	1.78	7.00	1,780.0	7.00	21.19
349	1.78	7.00	979.0	3.85	11.65
356	1.36	5.35	272.0	1.07	3.24
363	2.07	8.14	828.0	3.25	9.86

* = not calculated

Table 12: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 105.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/day/ha	FSx10^6 discharged/day	FSx10^6 discharged/day/ha	FSx10^6 discharged/day/animal
006	0.06	1.60	-*	-	-
013	1.87	49.96	-	-	-
027	0.33	8.82	-	-	-
034	0.21	5.61	504.0	13.47	16.26
041	0.30	8.01	27.0	0.72	0.87
049	0.33	8.82	23.1	0.62	0.75
055	0.37	9.89	144.3	3.86	4.65
062	0.19	5.08	81.7	2.18	2.64
069	0.27	7.21	251.1	6.71	8.10
076	1.28	34.20	14,080.0	376.17	454.19
083	1.61	43.01	17,710.0	473.15	571.29
090	0.48	12.82	110.4	2.95	3.56
097	0.30	8.01	225.0	6.01	7.26
104	0.21	5.61	8.4	0.22	0.27
111	0.21	5.61	14.7	0.39	0.47
118	0.37	9.89	55.5	1.48	1.79
125	0.77	20.57	1,848.0	49.37	59.61
132	0.33	8.82	13.2	0.35	0.43
139	0.33	8.82	306.9	8.20	9.90
147	0.19	5.08	2,090.0	55.84	67.42
153	0.19	5.08	2,090.0	55.84	67.42
160	0.05	1.34	1,200.0	32.06	38.71
167	0.03	0.80	720.0	19.24	23.23
174	0.002	0.05	48.0	1.28	1.55
181	0.003	0.08	33.0	0.88	1.06
188	0.002	0.05	4.2	0.11	0.14
195	5.51	147.21	132,240.0	3,532.99	4,265.81
202	0.82	21.91	19,680.0	525.78	634.84
209	0.08	2.14	1,760.0	47.02	56.77
216	0.06	1.60	2,340.0	62.52	75.48
223	0.03	0.80	1,200.0	32.06	38.71
230	0.13	3.47	1,690.0	45.15	54.52
237	0.03	0.80	600.0	16.03	19.35
244	0.57	15.23	29,070.0	776.65	937.74
251	0.09	2.40	1,350.0	36.07	43.55
258	0.05	1.34	260.0	6.95	8.39
265	0.04	1.07	232.0	6.20	7.48
272	0.61	16.30	3,355.0	89.63	108.23
280	0.21	5.61	1,008.0	26.93	32.52
287	0.30	8.01	990.0	26.45	31.94
293	0.52	13.89	1,092.0	29.17	35.23
301	0.27	7.21	391.5	10.46	12.63
307	0.21	5.61	1,239.0	33.10	39.97
314	0.27	7.21	3,240.0	86.56	104.52
321	0.30	8.01	210.0	5.61	6.77
328	0.21	5.61	52.5	1.40	1.69
335	0.30	8.01	810.0	21.64	26.13
342	0.17	4.54	110.5	2.95	3.56
349	0.17	4.54	59.5	1.59	1.92
356	0.11	2.94	82.5	2.20	2.66
363	0.30	8.01	450.0	12.02	14.52

* = not calculated

Table 13: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 106.

Day of 1975	Flow $Lx10^6$/day	Flow $Lx10^3$/ day/ha	$FSx10^6$ discharged/ day	$FSx10^6$ discharged/ day/ha	$FSx10^6$ discharged/ day/animal
006	0.11	1.24	-*	-	-
013	3.75	42.28	-	-	-
027	0.77	8.68	-	-	-
034	0.52	5.86	5,720.0	64.49	381.33
041	0.71	8.00	3,266.0	36.82	217.73
049	0.66	7.44	7,260.0	81.85	484.00
055	0.82	9.24	1,230.0	13.87	82.00
062	0.44	4.98	409.2	4.61	27.28
069	0.37	4.17	888.0	10.01	59.20
076	2.49	28.07	27,390.0	308.79	1,826.00
083	2.83	31.91	31,130.0	350.96	2,075.33
090	1.07	12.07	995.1	11.22	66.34
097	0.71	8.00	305.3	3.44	20.35
104	0.66	7.44	7,260.0	81.85	484.00
111	0.71	8.00	78.1	0.88	5.21
118	0.30	3.38	279.0	3.15	18.60
125	1.69	19.05	1,571.7	17.72	104.78
132	3.08	34.72	14,168.0	159.73	944.53
139	3.08	34.72	14,168.0	159.73	944.53
147	0.94	10.60	22,560.0	254.34	1,504.00
153	0.88	9.92	21,120.0	238.11	1,408.00
160	0.15	1.69	3,600.0	40.59	240.00
167	0.40	4.51	9,600.0	108.23	640.00
174	0.27	3.04	6,480.0	73.06	432.00
181	0.27	3.04	6,480.0	73.06	432.00
188	0.13	1.47	1,430.0	16.12	95.33
195	10.86	122.44	260,640.0	2,938.44	17,376.00
202	1.60	18.04	38,400.0	432.92	2,560.00
209	0.19	2.14	3,040.0	34.27	202.67
216	0.09	1.01	2,160.0	24.35	144.00
223	0.09	1.01	765.0	8.62	51.00
230	0.37	4.17	2,590.0	29.20	172.67
237	0.06	0.68	1,980.0	22.32	132.00
244	1.07	12.06	58,850.0	663.47	3,923.33
251	0.24	2.71	1,560.0	17.59	104.00
258	0.05	0.56	140.0	1.58	9.33
265	0.15	1.69	1,140.0	12.85	76.00
272	1.28	14.43	5,376.0	60.61	358.40
280	0.57	6.43	2,394.0	26.99	159.60
287	0.71	8.00	6,745.0	76.04	449.67
293	1.21	13.64	4,356.0	49.11	290.40
301	0.71	8.00	781.0	8.80	52.07
307	0.61	6.88	1,159.0	13.07	77.27
314	0.71	8.00	3,195.0	36.02	213.00
321	0.77	8.68	1,463.0	16.49	97.53
328	0.52	5.86	2,704.0	30.48	180.27
335	0.77	8.68	3,619.0	40.80	241.27
342	0.52	5.86	2,028.0	22.86	135.20
349	0.52	5.86	182.0	2.05	12.13
356	0.37	4.17	1,702.0	19.19	113.47
363	0.66	7.44	1,320.0	14.88	88.00

* not calculated

Table 14: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 107.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/day/ha	FSx10^6 discharged/day	FSx10^6 discharged/day/ha	FSx10^6 discharged/day/animal
006	0.04	1.36	-*	-	-
013	0.84	28.57	-	-	-
027	0.19	6.46	-	-	-
034	0.12	4.08	3.6	0.12	0.12
041	0.19	6.46	38.0	1.29	1.27
049	0.17	5.78	25.5	0.87	0.85
055	0.23	7.82	48.3	1.64	1.61
062	0.14	4.76	5.6	0.19	0.19
069	0.11	3.74	47.3	1.61	1.58
076	0.98	33.33	1,470.0	50.03	49.00
083	0.54	18.37	12,960.0	441.12	432.00
090	0.25	8.50	600.0	20.42	20.00
097	0.30	10.20	720.0	24.51	24.00
104	0.14	4.76	60.2	2.05	2.01
111	0.14	4.76	210.0	7.15	7.00
118	0.17	5.78	35.7	1.22	1.19
125	0.28	9.52	260.4	8.86	8.68
132	0.12	4.08	288.0	9.80	9.60
139	0.19	6.46	874.0	29.75	29.13
147	0.12	4.08	2,880.0	98.03	96.00
153	0.12	4.08	1,320.0	44.93	44.00
160	0.08	2.72	1,920.0	65.35	64.00
167	0.05	1.70	1,200.0	40.84	40.00
174	0.045	1.53	1,080.0	36.76	36.00
181	0.04	1.36	440.0	14.98	14.67
188	0.01	0.34	240.0	8.17	8.00
195	1.78	60.54	42,720.0	1,454.05	1,424.00
202	0.66	22.45	15,840.0	539.14	528.00
209	0.07	2.38	910.0	30.97	30.33
216	0.045	1.53	2,025.0	68.92	67.50
223	0.045	1.53	12,600.0	428.86	420.00
230	0.06	2.04	1,140.0	38.80	38.00
237	0.07	2.38	1,260.0	42.89	42.00
244	0.11	3.74	5,060.0	172.23	168.67
251	0.05	1.70	950.0	32.33	31.67
258	0.02	0.68	420.0	14.30	14.00
265	0.045	1.53	630.0	21.44	21.00
272	-	-	-	-	-
280	-	-	-	-	-
287	-	-	-	-	-
293	-	-	-	-	-
301	-	-	-	-	-
307	-	-	-	-	-
314	-	-	-	-	-
321	-	-	-	-	-
328	-	-	-	-	-
335	-	-	-	-	-
342	-	-	-	-	-
349	-	-	-	-	-
356	-	-	-	-	-
363	-	-	-	-	-

* = not calculated

Table 15: Fecal Streptococcus in surface water samples affected by water runoff and livestock density in watershed 108.

Day of 1975	Flow Lx10^6/day	Flow Lx10^3/day/ha	FSx10^6 discharged/day	FSx10^6 discharged/day/ha	FSx10^6 discharged/day/animal
006	0.30	2.04	-*	-	-
013	4.04	27.52	-	-	-
027	1.07	7.29	-	-	-
034	0.88	5.99	176.0	1.20	2.29
041	1.07	7.29	32.1	0.22	0.42
049	1.21	8.24	36.3	0.25	0.47
055	1.29	8.79	3,096.0	21.09	40.21
062	0.82	5.59	73.8	0.50	0.96
069	0.71	4.84	1,704.0	11.61	22.13
076	3.47	23.64	381.7	2.60	4.96
083	3.47	23.64	3,227.1	21.98	41.91
090	1.78	12.13	160.2	1.09	2.08
097	1.37	9.33	3,288.0	22.40	42.70
104	1.22	8.31	524.6	3.57	6.81
111	0.52	3.54	78.0	0.53	1.01
118	1.44	9.81	129.6	0.88	1.68
125	2.71	18.46	2,520.3	17.17	32.73
132	1.44	9.81	216.0	1.47	2.81
139	1.36	9.26	584.8	3.98	7.59
147	0.94	6.40	22,560.0	153.68	292.99
153	1.00	6.81	11,000.0	74.93	142.86
160	0.52	3.54	5,720.0	38.96	74.29
167	0.48	3.27	2,208.0	15.04	28.68
174	0.21	1.43	5,040.0	34.33	65.45
181	0.21	1.43	5,040.0	34.33	65.45
188	0.08	0.54	1,920.0	13.08	24.94
195	10.59	72.14	254,160.0	1,731.34	3,300.75
202	2.71	18.46	65,040.0	443.05	844.68
209	0.61	4.16	10,370.0	70.64	134.68
216	0.21	1.43	4,200.0	28.61	54.55
223	0.21	1.43	3,150.0	21.46	40.91
230	0.52	3.54	9,880.0	67.30	128.31
237	0.19	1.29	3,990.0	27.18	51.82
244	1.78	12.13	87,220.0	594.14	1,132.73
251	0.61	4.16	6,100.0	41.55	79.22
258	0.09	0.61	639.0	4.35	8.30
265	0.27	1.84	2,970.0	20.23	38.57
272	2.71	18.46	10,027.0	68.30	130.22
280	1.21	8.24	3,630.0	24.73	47.14
287	1.60	10.90	5,600.0	38.15	72.73
293	1.87	12.74	4,862.0	33.12	63.14
301	1.28	8.72	4,992.0	34.01	64.83
307	1.28	8.72	1,920.0	13.08	24.94
314	1.36	9.26	6,800.0	46.32	88.31
321	1.44	9.81	648.0	4.41	8.42
328	1.28	8.72	320.0	2.18	4.16
335	1.60	10.90	1,440.0	9.81	18.70
342	1.21	8.24	1,089.0	7.42	14.14
349	1.07	7.29	139.1	0.95	1.81
356	0.88	5.99	132.0	0.90	1.71
363	1.21	8.24	302.5	2.06	3.93

* = not calculated

Table 16: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 101 (North Branch).

	Coliforms			TVC Incubation	
Day of 1975	TC MPN/100 ml	FC MPN/100 ml	FC/TC Ratio	48 Hr. Cells/ml x 10^3	7 days Cells/ml x 10^3
006	2,400	1,100	0.46	2.0	6.0
013	2,400	11	0.005	660.0	830.0
027	240	25	0.10	3.0	13.0
034	460	460	1.0	240.0	570.0
041	43	43	1.0	TNTC*	TNTC
049	240	240	1.0	TNTC	TNTC
055	460	28	0.06	350.0	460.0
062	43	43	1.0	6.0	6.3
069	460	460	1.0	170.0	3,500.0
076	2,400	2,400	1.0	14.0	25.0
083	2,400	2,400	1.0	77.0	100.0
090	93	23	0.25	27.0	60.0
097	460	460	1.0	93.0	110.0
104	43	43	1.0	1.7	3.0
111	39	39	1.0	660.0	1,300.0
118	460	460	1.0	7.7	23.0
125	1,100	1,100	1.0	11.0	30.0
132	150	15	0.1	120.0	210.0
139	460	4	0.01	23.0	33.0
147	2,400	23	0.01	23.0	30.0
153	2,400	7	0.003	7.3	10.0
160	1,100	200	0.18	7.0	9.7
167	2,400	2,400	1.0	5.0	5.3
174	2,400	2,400	1.0	6.7	8.7
181	2,400	2,400	1.0	4.0	8.0
188	1,100	1,100	1.0	19.0	22.0
195	2,400	2,400	1.0	700.0	TNTC
202	2,400	2,400	1.0	94.0	150.0

*TNTC = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 17: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 101 (North Branch).

	Coliforms			TVC Incubation	
Day of	TC	FC	FC/TC	48 hr.	7 days
1975	Cells/100 ml		Ratio	Cells x 10^3/ml	
209	1200	300	0.25	TNTC*	TNTC
216	2100	300	0.14	2.0	2.0
223	1200	250	0.21	25.0	25.0
230	2100	350	0.17	13.0	19.0
237	1000	120	0.12	19.0	TNTC
244	5300	960	0.18	35.5	46.0
251	1700	190	0.11	5.7	7.0
258	1600	180	0.11	10.0	33.3
265	1100	250	0.23	4.7	6.0
272	750	120	0.16	11.0	14.3
280	350	40	0.11	3.7	6.3
287	430	250	0.58	13.0	17.3
293	580	120	0.21	1.7	4.3
301	100	15	0.15	8.0	10.6
307	10	10	1.00	4.0	5.3
314	440	440	1.00	6.5	9.3
321	50	-**	-	2.9	4.1
328	50	50	1.00	2.5	3.7
335	-	60	-	6.1	7.9
342	-	95	-	2.2	6.0
349	-	40	-	0.97	1.2
356	-	10	-	1.1	1.7
363	-	3	-	3.3	4.2

* = Too numerous to count
** = Not tested
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 18: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 102 (Blue Jay Branch).

	Coliforms			TVC Incubation	
Day of 1975	TC MPN/100 ml	FC MPN/100 ml	FC/TC Ratio	48 hr. Cells/ml x 10^3	7 days Cells/ml x 10^3
006	93	43	0.46	2.6	8.2
013	1,100	460	0.42	20.0	50.0
027	240	240	1.0	6.0	42.0
034	460	240	0.52	590.0	690.0
041	460	460	1.0	TNTC*	TNTC
049	39	39	1.0	TNTC	TNTC
055	93	93	1.0	37.0	93.0
062	43	15	0.35	13.0	23.0
069	43	43	1.0	2.0	3.7
076	240	240	1.0	18.0	34.0
083	2,400	2,400	1.0	67.0	87.0
090	240	93	0.39	310.0	350.0
097	43	43	1.0	2.7	10.0
104	460	460	1.0	490.0	500.0
111	460	460	1.0	TNTC	TNTC
118	460	460	1.0	2.7	14.0
125	240	240	1.0	4.0	11.0
132	240	9	0.04	13.0	20.0
139	240	3	0.01	11.0	23.0
147	460	3	0.01	40.0	60.0
153	460	3	0.01	10.0	TNTC
160	2,400	2,400	1.0	90.0	160.0
167	2,400	2,400	1.0	4.0	5.3
174	1,100	1,100	1.0	5.7	7.0
181	2,400	2,400	1.0	5.7	9.0
188	no flow	no flow	no flow	no flow	no flow
195	2,400	2,400	1.0	82.0	110.0
202	2,400	2,400	1.0	72.0	80.0

*TNTC = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 19: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 102 (Blue Jay Branch).

Day of 1975	Coliforms TC	FC	FC/TC Ratio	TVC Incubation 48 hr.	7 days
	Cells/100 ml			Cells x 10^3/ml	
209	930	100	0.11	6.7	7.3
216	3900	150	0.04	60.0	80.0
223	1000	400	0.40	20.0	30.0
230	3000	320	0.01	14.7	16.7
237	2200	190	0.09	19.7	23.3
244	3900	2200	0.56	125.0	145.0
251	1500	260	0.17	10.0	13.0
258	1400	320	0.23	3.3	6.0
265	1200	280	0.23	4.7	7.3
272	1300	210	0.16	19.3	29.6
280	450	50	0.11	4.0	10.7
287	360	140	0.39	73.0	96.0
293	640	220	0.34	4.3	9.0
301	120	120	1.00	160.0	320.0
307	60	55	0.92	6.0	13.0
314	310	310	1.00	4.7	7.1
321	260	260	1.00	4.9	7.7
328	70	65	0.93	2.6	4.1
335	-*	290	-	5.8	7.2
342	-	15	-	2.2	3.8
349	-	20	-	1.2	1.9
356	-	190	-	2.1	3.3
363	-	40	-	1.9	TNTC**

* = Not tested
** = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 20: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 103 (Williamson Branch).

	Coliforms			TVC Incubation	
Day of	TC	FC	FC/TC	48 hr.	7 days
1975	MPN/100 ml		Ratio	Cells/ml x 10^3	
006	1,100	210	0.19	4.0	8.0
013	2,400	lost	-	370.0	700.0
027	43	43	1.0	7.2	22.0
034	43	43	1.0	7.0	TNTC*
041	43	43	1.0	TNTC	TNTC
049	460	460	1.0	1,700.0	2,200.0
055	75	43	0.57	4.0	15.0
062	93	93	1.0	57.0	67.0
069	93	43	0.46	30.0	450.0
076	240	240	1.0	8.0	13.0
083	2,400	2,400	1.0	20.0	93.0
090	150	23	0.15	32.0	33.0
097	43	43	1.0	2.0	8.3
104	39	39	1.0	37.0	57.0
111	23	23	1.0	3.7	16.0
118	23	23	1.0	TNTC	TNTC
125	240	240	1.0	4.7	17.0
132	460	9	0.02	13.0	22.0
139	240	4	0.02	3.7	15.0
147	240	3	0.01	3.7	8.3
153	1,100	4	0.004	7.0	15.0
160	460	460	1.0	6.7	9.0
167	2,400	2,400	1.0	260.0	340.0
174	460	460	1.0	4.3	7.3
181	2,400	2,400	1.0	37.0	47.0
188	no flow	no flow	no flow	no flow	no flow
195	2,400	2,400	1.0	39.0	56.0
202	2,400	2,400	1.0	7.0	12.0

*TNTC = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 21: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 103 (Williamson Branch).

	Coliforms			TVC Incubation	
Day of	TC	FC	FC/TC	48 hr.	7 days
1975	Cells/100 ml		Ratio	Cells x 10^3/ml	
209	800	130	0.16	TNTC*	TNTC
216	1800	100	0.06	2.0	3.0
223	950	150	0.16	6.0	10.3
230	1800	130	0.07	10.3	11.3
237	-**	-	-	36.7	56.7
244	5400	2500	0.46	75.0	105.0
251	2000	130	0.07	4.3	7.7
258	1500	280	0.19	1.3	7.0
265	950	100	0.11	13.3	20.0
272	1100	190	0.17	206.0	262.0
280	300	85	0.28	4.3	7.0
287	160	50	0.31	-	-
293	660	140	0.21	1.0	3.9
301	190	45	0.24	4.7	6.6
307	60	20	0.33	20.0	47.0
314	110	110	1.00	6.1	8.6
322	70	70	1.00	1.8	3.5
328	30	25	0.83	1.4	3.8
335	-	95	-	3.3	5.2
342	-	130	-	1.4	3.8
349	-	20	-	0.70	1.6
356	-	110	-	0.53	1.6
363	-	15	-	1.2	2.3

* = Too numerous to count
** = Not tested
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 22: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 105 (Sellman North).

	Coliforms			TVC Incubation	
Day of 1975	TC MPN/100 ml	FC	FC/TC Ratio	48 hr. Cells/ml x 10^3	7 days
006	1,100	460	0.42	1.0	15.0
013	1,100	210	0.19	70.0	230.0
027	93	15	0.16	5.1	42.0
034	460	150	0.33	53.0	85.0
041	93	93	1.0	TNTC*	TNTC
049	240	240	1.0	8.0	15.0
055	43	43	1.0	2.0	4.7
062	43	43	1.0	2.3	4.7
069	240	240	1.0	13.0	57.0
076	460	460	1.0	7.7	13.0
083	240	240	1.0	43.0	70.0
090	240	240	1.0	83.0	97.0
097	93	23	0.25	37.0	53.0
104	2,400	2,400	1.0	4.0	7.3
111	43	43	1.0	340.0	550.0
118	43	43	1.0	TNTC	TNTC
125	240	240	1.0	8.3	21.0
132	240	93	0.39	19.0	27.0
139	460	4	0.01	16.0	TNTC
147	2,400	9	0.003	4.7	TNTC
153	460	3	0.01	4.7	7.0
160	1,100	200	0.18	50.0	97.0
167	2,400	2,400	1.0	8.3	11.0
174	2,400	2,400	1.0	2.0	3.7
181	2,400	2,400	1.0	4.0	7.7
188	2,400	460	0.19	TNTC	TNTC
195	2,400	2,400	1.0	57.0	73.0
202	2,400	2,400	1.0	33.0	43.0

*TNTC = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 23: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 105 (Sellman North).

	Coliforms			TVC Incubation	
Day of 1975	TC	FC	FC/TC Ratio	48 hr	7 days
	Cells/100 ml			Cells x 10^3/ml	
209	1700	430	0.25	40.0	TNTC*
216	3200	100	0.03	113.0	133.0
223	2600	500	0.19	TNTC	TNTC
230	1700	390	0.23	6.3	7.0
237	1700	680	0.40	23.0	27.0
244	3000	540	0.18	33.0	40.7
251	1700	220	0.13	8.7	10.0
258	2400	250	0.10	13.0	14.7
265	1600	280	0.18	7.0	8.3
272	1100	320	0.29	25.0	36.0
280	800	60	0.08	9.3	12.7
287	440	220	0.50	200.0	276.0
293	740	110	0.15	8.0	14.0
301	290	120	0.41	3.3	5.6
307	1000	1000	1.00	2.6	5.3
314	790	790	1.00	9.0	19.3
321	50	35	0.70	1.4	6.5
328	55	55	1.00	2.2	3.6
335	-**	130	-	21.7	28.3
342	-	85	-	2.3	3.8
349	-	20	-	1.5	2.2
356	-	5	-	1.4	2.8
363	-	110	-	2.0	3.9

TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts
* = Too numerous to count
** = Not tested

Table 24: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 106 (Sellman South).

Day of 1975	Coliforms		FC/TC Ratio	TVC Incubation	
	TC	FC		48 hr.	7 days
	MPN/100 ml			Cells/ml x 10^3	
006	240	240	1.0	1.0	14.0
013	2,400	2,400	1.0	560.0	1400.0
027	460	240	0.52	8.2	14.0
034	240	240	1.0	TNTC*	TNTC
041	1,100	1,100	1.0	TNTC	TNTC
049	210	210	1.0	15.0	32.0
055	460	460	1.0	3.3	5.7
062	460	460	1.0	3.7	5.7
069	240	240	1.0	3.7	5.3
076	2,400	2,400	1.0	11.0	36.0
083	2,400	2,400	1.0	130.0	200.0
090	1,100	75	0.07	490.0	520.0
097	1,100	210	0.19	2.0	5.7
104	150	150	1.0	8.0	10.0
111	43	43	1.0	30.0	57.0
118	460	460	1.0	5.7	20.0
125	460	460	1.0	9.7	23.0
132	2,400	210	0.09	250.0	290.0
139	2,400	150	0.06	29.0	40.0
147	2,400	93	0.04	27.0	40.0
153	2,400	3	0.001	9.0	14.0
160	2,400	2,400	1.0	21.0	28.0
167	2,400	2,400	1.0	7.0	9.7
174	2,400	210	0.09	18.0	23.0
181	2,400	2,400	1.0	11.0	21.0
188	2,400	2,400	1.0	520.0	570.0
195	2,400	2,400	1.0	59.0	87.0
202	2,400	2,400	1.0	27.0	50.0

*TNTC - too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 25: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 106 (Sellman South).

	Coliforms			TVC Incubation	
Day of 1975	TC	FC	FC/TC Ratio	48 hr.	7 days
	Cells/100 ml			Cells x 10^3/ml	
209	1630	370	0.23	4.3	7.0
216	2300	350	0.15	26.7	46.7
223	1300	400	0.31	140.0	170.0
230	2100	230	0.11	510.0	580.0
237	3200	150	0.05	28.7	34.3
244	4600	1200	0.26	120.0	157.0
251	3400	240	0.07	TNTC*	TNTC
258	900	140	0.16	0.67	2.3
265	1700	610	0.36	4.7	8.7
272	1300	320	0.25	25.3	29.3
280	700	380	0.54	3.3	6.3
287	450	450	1.00	77.0	TNTC
293	1200	680	0.57	4.3	6.6
301	160	160	1.00	13.0	13.0
307	200	200	1.00	3.3	6.7
314	660	660	1.00	9.2	10.3
321	160	160	1.00	2.7	5.5
328	210	210	1.00	3.1	5.1
335	-**	280	-	18.3	21.7
342	-	160	-	5.3	6.8
349	-	30	-	1.1	1.6
356	-	180	-	3.0	4.0
363	-	83	-	3.5	5.3

TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts
* = Too numerous to count
** = Not tested

Table 26: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 107 (Fox Creek).

	Coliforms			TVC Incubation	
Day of 1975	TC	FC	FC/FC Ratio	48 hr.	7 days
	MPN/100 ml			Cells/ml x 10^3	
006	4	4	1.0	2.3	4.3
013	-*	-	-	-	-
027	9	9	1.0	8.0	25.0
034	43	9	0.21	TNTC**	TNTC
041	93	4	0.04	TNTC	TNTC
049	15	3	0.2	210.0	550.0
055	21	4	0.19	TNTC	TNTC
062	93	15	0.16	TNTC	TNTC
069	43	23	0.53	1.0	1.3
076	150	75	0.50	8.3	21.0
083	2,400	2,400	1.0	13.0	53.0
090	43	23	0.53	10.0	13.0
097	75	20	0.27	1.7	15.0
104	93	43	0.46	4.0	6.7
111	23	9	0.39	TNTC	TNTC
118	9	9	1.0	5.0	21.0
125	460	460	1.0	47.0	83.0
132	93	4	0.04	16.0	23.0
139	93	3	0.03	11.0	19.0
147	460	14	0.03	33.0	40.0
153	2,400	3	0.001	27.0	36.0
160	2,400	2,400	1.0	9.0	13.0
167	2,400	2,400	1.0	5.3	7.7
174	2,400	460	0.19	3.0	6.3
181	2,400	460	0.19	7.3	TNTC
188	2,400	2,400	1.0	59.0	73.0
195	2,400	2,400	1.0	1200.0	TNTC
202	2,400	2,400	1.0	22.0	25.0

* Not tested

**Too numerous to count

TC = Total coliforms

FC = Fecal coliforms

TVC = Total viable counts

Table 27: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 107 (Fox Creek).

	Coliforms			TVC Incubation	
Day of 1975	TC	FC	FC/TC Ratio	48 hr.	7 days
	Cells/100 ml			Cells x 10^3/ml	
209	1400	130	0.09	4.0	6.7
216	1900	150	0.08	26.7	36.7
223	3700	50	0.01	40.7	65.5
230	4300	1100	0.26	18.0	21.0
237	1000	45	0.05	11.0	14.0
244	3800	1200	0.32	180.0	TNTC*
251	1900	330	0.17	7.7	TNTC
258	1900	110	0.06	4.0	4.7
265	2400	610	0.25	7.3	9.0
272	300	5	0.02	98.0	106.0
280	250	10	0.04	13.3	37.0
287	140	5	0.04	34.7	35.6
293	560	25	0.04	21.3	23.3
301	180	15	0.08	10.3	13.3
307	40	25	0.63	4.6	9.3
314	60	60	1.00	3.9	6.0
321	20	10	0.50	4.3	14.0
328	3	3	1.00	3.1	4.5
335	-**	10	-	4.0	6.0
342	-	5	-	.97	2.4
349	-	5	-	.87	1.0
356	-	3	-	2.2	3.5
363	-	5	-	1.7	2.7

TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts
* = Too numerous to count
** = Not tested

Table 28: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria (TVC) in surface samples at weir 108 (Steinlein).

	Coliforms			TVC Incubation	
Day of 1975	TC MPN/100 ml	FC MPN/100 ml	FC/TC ratio	48 hr. Cells/ml x 10^3	7 days Cells/ml x 10^3
006	93	23	0.25	1.0	9.0
013	240	240	1.0	660.0	820.0
027	20	20	1.0	TNTC*	TNTC
034	43	23	0.53	TNTC	TNTC
041	43	23	0.53	TNTC	TNTC
049	150	150	1.0	40.0	85.0
055	210	210	1.0	57.0	120.0
062	240	240	1.0	4.3	19.0
069	2,400	2,400	1.0	13.0	47.0
076	1,100	1,100	1.0	5.0	9.7
083	240	240	1.0	7.7	14.0
090	93	23	0.25	31.0	35.0
097	23	23	1.0	3.0	7.7
104	4	4	1.0	2.3	6.7
111	150	150	1.0	TNTC	TNTC
118	93	93	1.0	TNTC	TNTC
125	43	43	1.0	9.0	30.0
132	240	3	0.01	60.0	110.0
139	93	4	0.04	7.0	25.0
147	240	3	0.01	20.0	40.0
153	460	4	0.01	8.3	12.0
160	1,100	1,100	1.0	18.0	23.0
167	240	240	1.0	2.0	6.0
174	1,100	1,100	1.0	17.0	22.0
181	2,400	2,400	1.0	17.0	22.0
188	2,400	28	0.01	78.0	110.0
195	2,400	2,400	1.0	54.0	65.0
202	2,400	2,400	1.0	32.0	40.0

*TNTC = Too numerous to count
TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts

Table 29: Estimated total and fecal coliform bacteria, FC/TC ratio, and total viable aerobic heterotrophic bacteria in surface samples at weir 108 (Steinlein).

	Coliforms			TVC Incubation	
Day of 1975	TC	FC	FC/TC Ratio	48 hr.	7 days
	Cells/100 ml			Cells x 10^3/ml	
209	930	430	0.46	3.0	6.0
216	850	350	0.41	10.5	11.5
223	550	50	0.09	42.0	50.0
230	1000	95	0.10	7.3	10.7
237	2400	110	0.05	31.0	39.0
244	2500	500	0.20	160.0	180.0
251	1800	150	0.08	9.0	12.3
258	1000	70	0.07	4.5	7.5
265	1100	280	0.25	TNTC*	TNTC
272	1200	180	0.15	8.0	11.0
280	650	115	0.18	17.0	TNTC
287	350	85	0.24	19.0	23.6
293	480	180	0.38	7.0	17.0
301	270	260	0.96	4.3	7.6
307	60	55	0.92	2.3	5.0
314	220	220	1.00	5.7	6.8
322	20	20	1.00	2.8	4.1
328	40	18	0.45	1.8	2.9
335	-**	65	-	5.5	7.3
342	-	15	-	3.1	4.8
349	-	95	-	1.1	3.0
356	-	5	-	1.7	3.6
363	-	10	-	3.2	5.4

TC = Total coliforms
FC = Fecal coliforms
TVC = Total viable counts
* = Too numerous to count
** = Not tested

Table 30: Estimated total and fecal Streptococci, FC/FS ratio, and *Salmonella*-like bacteria in surface samples at weir 101 (North Branch).

	Streptococci			Salmonella
Day of 1975	TS	FS	FC/FS Ratio	
	MPN/100 ml			MPN/100 ml
006	460	-*	-	11
013	2,400	-	-	23
027	93	-	-	93
034	21	15	30.7	43
041	240	240	0.18	23
049	240	240	1.0	43
055	2,400	2,400	0.01	43
062	460	150	0.29	23
069	240	240	1.9	23
076	1,100	1,100	2.2	2,400
083	2,400	2,400	1.0	2,400
090	93	21	1.1	93
097	240	240	1.9	15
104	9	9	4.8	23
111	28	28	1.4	93
118	240	240	1.9	240
125	20	20	55.0	1,100
132	93	93	0.16	23
139	93	93	0.04	460
146	2,400	2,400	0.01	240
153	460	460	0.02	2,400
160	2,400	2,400	0.08	2,400
167	2,400	2,400	1.0	2,400
174	2,400	2,400	1.0	2,400
181	2,400	2,400	1.0	2,400
188	2,400	2,400	0.46	1,100
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	2,400

* = Not tested.

Table 31: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 101 (North Branch).

Day of 1975	FS Cells/100 ml	FC/FS ratio	Salmonella MPN/100 ml
209	1,100	0.27	1,100
216	2,800	0.11	2,400
223	1,700	0.15	2,400
230	1,300	0.27	2,400
237	1,900	0.06	2,400
244	3,600	0.27	2,400
251	750	0.25	2,400
258	780	0.23	2,400
265	970	0.26	2,100
272	420	0.29	4,600
280	510	0.08	2,400
287	390	0.64	1,500
293	190	0.63	1,500
301	160	0.09	2,400
307	120	0.08	430
314	400	1.10	150
321	185	-*	230
328	50	1.00	430
335	190	0.32	-
342	140	0.68	-
349	410	0.10	-
356	110	0.09	-
363	40	0.08	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 32: Estimated total and fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 102 (Blue Jay Branch).

	Streptococci			Salmonella
Day of 1975	TS	FS	FC/FS Ratio	
	MPN/100 ml			MPN/100 ml
006	20	-*	-	23
013	120	-	-	240
027	150	-	-	460
034	150	75	3.2	43
041	2,400	1,100	0.42	43
049	210	23	1.7	93
055	240	240	0.39	43
062	3	3	5.0	23
069	14	9	4.7	93
076	210	210	1.1	1,100
083	1,100	1,100	2.2	460
090	23	3	31.0	1,100
097	43	43	1.0	75
104	4	4	115.0	43
111	7	7	66.0	1,100
118	23	23	20.0	75
125	93	93	2.6	75
132	150	20	0.45	460
139	93	93	0.03	75
146	460	460	0.01	460
153	1,100	1,100	0.003	2,400
160	2,400	2,400	1.0	1,100
167	2,400	2,400	1.0	2,400
174	2,400	2,400	.46	2,400
181	1,100	1,100	2.2	2,400
188	no flow	no flow	no flow	no flow
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	2,400

* = Not tested.

Table 33: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 102 (Blue Jay Branch).

Day of 1975	FS Cells/100 ml	FC/FS ratio	Salmonella MPN/100 ml
209	1,100	0.09	2,400
216	4,100	0.04	2,400
223	2,300	0.17	2,400
230	1,900	0.17	2,400
237	3,400	0.06	2,400
244	6,600	0.33	2,400
251	700	0.37	2,400
258	840	0.38	1,100
265	590	0.47	2,400
272	1,000	0.21	4,600
280	510	0.10	2,400
287	650	0.22	430
293	400	0.55	4,600
301	410	0.29	2,400
307	260	0.21	1,500
314	1,200	0.26	930
321	260	1.00	930
328	70	0.93	230
335	370	0.78	-*
342	95	0.16	-
349	90	0.22	-
356	230	0.83	-
363	78	0.51	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 34: Estimated total and fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 103 (Williamson Branch).

	Streptococci			Salmonella
Day of 1975	TS MPN/100 ml	FS MPN/100 ml	FC/FS Ratio	MPN/100 ml
006	23	-*	-	43
013	2,400	-	-	240
027	9	-	-	460
034	23	23	1.9	23
041	2,400	93	0.46	23
049	460	460	1.0	93
055	460	150	0.29	93
062	9	4	23.3	93
069	43	15	2.9	23
076	93	93	2.6	39
083	460	460	5.2	1,100
090	4	4	5.8	93
097	23	23	1.9	20
104	4	4	9.8	23
111	9	9	2.6	93
118	15	15	1.5	43
125	23	23	10.4	240
132	23	9	1.0	2,400
139	93	93	0.04	150
146	150	150	0.02	2,400
153	460	460	0.01	2,400
160	2,400	2,400	0.19	75
167	2,400	2,400	1.0	2,400
174	1,100	1,100	.42	2,400
181	240	240	10.0	1,100
188	no flow	no flow	no flow	no flow
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	2,400

* = not tested.

Table 35: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 103 (Williamson Branch).

Day of 1975	FS Cells/100 ml	FC/FS Ratio	Salmonella MPN/100 ml
209	800	0.16	1,100
216	2,100	0.05	2,400
223	900	0.17	2,400
230	650	0.20	2,400
237	-*	-	2,400
244	6,000	0.42	2,400
251	800	0.16	1,500
258	490	0.57	2,400
265	660	0.15	930
272	360	0.53	11,000
280	270	0.31	930
287	330	0.15	430
293	200	0.70	4,600
301	210	0.21	750
307	70	0.29	930
314	790	0.14	750
322	90	0.78	430
328	140	0.18	230
335	210	0.45	-
342	100	1.30	-
349	55	0.36	-
356	20	5.50	-
363	40	0.38	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 36: Estimated total and fecal Streptococci, FC/FS ratio, and *Salmonella*-like bacteria in surface samples at weir 105 (Sellman North).

	Streptococci			Salmonella
Day of 1975	TS	FS	FC/FS Ratio	
	MPN/100 ml			MPN/100 ml
006	15	-*	-	3
013	2,400	-	-	240
027	43	-	-	93
034	240	240	0.63	93
041	1,000	9	10.3	20
049	12	7	34.3	1,100
055	39	39	1.1	23
062	43	43	1.0	23
069	93	93	2.6	460
076	1,100	1,100	0.42	460
083	1,100	1,100	0.22	43
090	23	23	10.4	75
097	75	75	0.31	240
104	4	4	600.0	9
111	7	7	6.1	21
118	15	15	2.9	4
125	240	240	1.0	240
132	4	4	23.3	1,100
139	93	93	0.04	240
146	1,100	1,100	0.01	150
153	1,100	1,100	0.003	1,100
160	2,400	2,400	0.08	1,100
167	2,400	2,400	1.0	2,400
174	2,400	2,400	1.0	2,400
181	2,400	1,100	2.2	2,400
188	1,100	210	2.2	460
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	2,400

* = Not tested.

Table 37: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 105 (Sellman North).

Day of 1975	FS Cells/100 ml	FC/FS Ratio	Salmonella MPN/100 ml
209	2,200	0.20	1,100
216	3,900	0.03	2,400
223	4,000	0.13	2,400
230	1,300	0.30	2,400
237	2,000	0.34	2,400
244	5,100	0.11	2,400
251	1,500	0.15	2,400
258	520	0.47	2,400
265	580	0.48	4,600
272	550	0.58	4,600
280	480	0.13	2,400
287	330	0.67	1,200
293	210	0.52	230
301	145	0.83	430
307	590	1.69	2,400
314	1,200	0.66	930
321	70	0.50	230
328	25	2.20	150
335	270	0.48	-*
342	65	1.31	-
349	35	0.57	-
356	75	0.07	-
363	150	0.73	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 38: Estimated total and fecal Streptococci, FC/FS ratio, and *Salmonella*-like bacteria in surface samples at weir 106 (Sellman South).

	Streptococci			Salmonella
Day of 1975	TS	FS	FC/FS Ratio	
	MPN/100 ml			MPN/100 ml
006	460	-*	-	9
013	2,400	-	-	240
027	14	-	-	43
034	1,100	1,100	0.22	15
041	2,400	460	2.4	93
049	1,100	1,100	0.19	240
055	460	150	3.1	23
062	150	93	4.9	43
069	240	240	1.0	43
076	1,100	1,100	2.2	2,400
083	1,100	1,100	2.2	240
090	93	93	0.81	150
097	43	43	4.9	43
104	1,100	1,100	0.14	39
111	11	11	3.9	93
118	93	93	5.0	150
125	93	93	5.0	43
132	460	460	0.46	460
139	460	460	0.33	1,100
146	2,400	2,400	0.04	2,400
153	2,400	2,400	0.001	2,400
160	2,400	2,400	1.0	2,400
167	2,400	2,400	1.0	2,400
174	2,400	2,400	0.09	2,400
181	2,400	2,400	1.0	2,400
188	1,100	1,100	2.2	2,400
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	2,400

* = Not tested.

Table 39: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 106 (Sellman South).

Day of 1975	FS Cells/100 ml	FC/FS Ratio	Salmonella MPN/100 ml
209	1,600	0.23	1,100
216	2,400	0.15	2,400
223	850	0.47	2,400
230	700	0.33	2,400
237	3,300	0.05	2,400
244	5,500	0.22	2,400
251	650	0.37	11,000
258	280	0.50	2,400
265	760	0.80	11,000
272	420	0.76	2,400
280	420	0.90	4,600
287	950	0.47	750
293	360	1.89	930
301	110	1.45	4,600
307	190	1.05	750
314	450	1.47	2,400
321	190	0.84	230
328	520	0.40	230
335	470	0.60	-*
342	390	0.41	-
349	35	0.86	-
356	460	0.39	-
363	200	0.42	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 40: Estimated total and fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 107 (Fox Creek).

	Streptococci			Salmonella
Day of 1975	TS MPN/100 ml	FS	FC/FS Ratio	MPN/100 ml
006	43	-*	-	4
013	-	-	-	-
027	9	-	-	23
034	3	3	3.0	23
041	28	20	0.2	9
049	25	15	0.2	1,100
055	93	21	0.19	23
062	9	4	3.8	23
069	43	43	0.53	4
076	150	150	0.5	2,400
083	2,400	2,400	1.0	2,400
090	240	240	0.10	93
097	240	240	0.08	4
104	43	43	1.0	23
111	150	150	0.06	15
118	21	21	0.43	4
125	93	93	5.0	23
132	240	240	0.02	93
139	460	460	0.01	93
146	2,400	2,400	0.01	2,400
153	1,100	1,100	0.003	2,400
160	2,400	2,400	1.0	2,400
167	2,400	2,400	1.0	2,400
174	2,400	2,400	0.19	1,100
181	1,100	1,100	0.42	2,400
188	2,400	2,400	1.0	2,400
195	2,400	2,400	1.0	2,400
202	2,400	2,400	1.0	1,100

* = Not tested.

Table 41: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 107 (Fox Creek).

Day of 1975	FS Cells/100 ml	FC/FS Ratio	Salmonella MPN/100 ml
209	1,300	0.10	2,400
216	4,500	0.03	2,400
223	28,000	0.01	2,400
230	1,900	0.58	2,400
237	1,800	0.03	2,400
244	4,600	0.26	2,400
251	1,900	0.17	750
258	2,100	0.05	1,100
265	1,400	0.44	2,400
272	320	0.02	430
280	330	0.03	2,400
287	490	0.01	430
293	250	0.10	1,200
301	130	0.12	1,500
307	110	0.23	1,500
314	660	0.09	230
321	170	0.06	90
328	30	0.10	90
335	950	0.01	-*
342	20	0.25	-
349	10	0.50	-
356	40	0.08	-
363	13	0.38	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms

Table 42: Estimated total and fecal Streptococci, FC/FS ratio, and *Salmonella*-like bacteria in surface samples at weir 108 (*Steinlein*).

	Streptococci			Salmonella
Day of 1975	TS	FS	FC/FS Ratio	
	MPN/100 ml			MPN/100 ml
006	9	-*	-	15
013	1,100	-	-	240
027	43	-	-	21
034	20	20	1.2	23
041	-	3	7.7	4
049	21	3	50.0	460
055	240	240	0.88	43
062	9	9	26.7	75
069	240	240	10.0	460
076	21	11	100.0	23
083	93	93	2.6	43
090	23	9	2.6	43
097	240	240	0.1	93
104	43	43	0.10	20
111	15	15	10.0	23
118	9	9	10.3	43
125	93	93	0.46	240
132	15	15	0.2	460
139	43	43	0.09	150
146	2,400	2,400	0.001	210
153	1,100	1,100	0.004	2,400
160	1,100	1,100	1.0	240
167	460	460	0.52	1,100
174	2,400	2,400	0.46	2,400
181	2,400	2,400	1.0	2,400
188	2,400	2,400	0.01	2,400
195	2,400	2,400	1.0	1,100
202	2,400	2,400	1.0	2,400

* = Not tested.

Table 43: Estimated fecal Streptococci, FC/FS ratio, and Salmonella-like bacteria in surface samples at weir 108 (Steinlein).

Day of 1975	FS Cells/100 ml	FC/FS Ratio	Salmonella MPN/100 ml
209	1,700	0.25	2,400
216	2,000	0.18	2,400
223	1,500	0.03	2,400
230	1,900	0.05	2,400
237	2,100	0.05	2,400
244	4,900	0.10	2,400
251	1,000	0.15	2,400
258	710	0.10	2,400
265	1,100	0.25	1,500
272	370	0.49	11,000
280	300	0.38	750
287	350	0.24	930
293	260	0.69	4,600
301	390	0.67	4,600
307	150	0.37	-*
314	500	0.44	430
322	45	0.44	230
328	25	0.72	430
335	90	0.72	-
342	90	0.17	-
349	13	7.31	-
356	15	0.33	-
363	25	0.40	-

* = Not tested
FS = Fecal Streptococci
FC = Fecal coliforms